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CONTENTS

Raymond H. Torrey ..... *James Murphy* 433

A large species of Rhizophidium from cooked beef ..... *J. S. Karling* 439

Thiamin and growth of Pythium Butleri ..... *William J. Robbins and Frederick Kavanagh* 453

Studies in the American Celastraceae I. New species of Microtropis, Wimmeria and Zinowiewia ..... *C. L. Lundell* 463

The emergence of smut-inoculated oat seedlings through sand and loam soil ..... *Paul F. Brandwein* 477

Salt spray: an important factor in coastal ecology ..... *B. W. Wells and I. V. Shunk* 485

Index to American Botanical Literature 493

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Raymond H. Torrey

James Murphy

Raymond Hezekiah Torrey was born in Georgetown, Massachusetts, on July 15th, 1880. He died in New York City, July 15th, 1938, his 58th birthday. He was the son of Grafton F. Torrey and Leonora Warren, both of whom were born at Deer Isle, Maine.

On his father's side he was related to John Torrey, the American botanist. His mother was a descendant of Richard Warren, who landed at Plymouth on the "Mayflower," and of General Joseph Warren, who was killed at Bunker Hill. His father and uncles were all seafaring men, and from them, as a boy, he heard many tales of adventure and distant places, which left a very vivid impress on his memory. He was a life member of the National Society of Puritan Descendants.

His early education was received in Georgetown. While in grammar school he became acquainted with Mr. and Mrs. Horner, local botanists, who were employed by Harvard College to collect specimens for use in classes in botany. Mr. Torrey frequently went with them after school and on weekends in search of specimens, and it became necessary in the pursuit of some rarer species to go even further and further afield due to their disappearance as a result of indiscriminate collecting. It was this fact that first directed Mr. Torrey's attention not only to tramping out-of-doors, but particularly to the urgency of the conservation and protection of our native flora. His interest in botany was further stimulated by his instructor in high school.

Upon graduation from the Georgetown High School in 1896, he obtained employment in the local newspaper, performing the varied tasks of editor, reporter, typesetter, and on occasion operated and even tended to and stoked the steam boiler which supplied the power. This journalistic experience, however, aided him in obtaining a position on the "Springfield Union." In 1903 he came to New York and entered the employ of the New York City News Association, as assistant to the night city editor and was later engaged by the "New York American" and "Herald Tribune." On the two latter papers he attained the position of Night City Editor. He conducted a column in the "New York Post" for many years, until his death, under "The Long Brown Path," which was devoted to life out-of-doors and to scientific aspects of nature.

His interest in botany led him to become a member of the Torrey Botanical Club which he did in 1920. The numerous articles and notes in "Torreya" attest to his enthusiasm for botany, and particularly to those

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Raymond H. Torrey

boreal plants found on high elevations throughout the club area, which are generally considered glacial relicts.

In his later years, due to the encouragement and inspiration of Dr. Alexander W. Evans, his interest was aroused in lichens, particularly the genus *Cladonia*, in which the club territory is particularly rich in species, forms and modifications. As the fruit of his travels and studies he contributed to "Torreya" an article "Cladoniae in the Range of the Torrey Botanical Club," which was profusely illustrated and constitutes the principal source of scientific knowledge and information on that subject available to those interested in the Cladoniae of this region. This was followed by other articles in "Torreya" on the same subject.

His native zeal and infectious enthusiasm stirred other students to an intensive pursuit of lichens generally, and particularly of the genus *Cladonia*. Prior to his death he had gathered together material for a memoir on the subject, with particular relation to the species *Cladonia Boryi* Tuck. which is found generally along the coast. The study was intended to embrace the area from Newfoundland to North Carolina as far as Nag's Head.

As a result of his apparently well-night indefatigable energy, as well as enthusiasm, he assembled probably the most complete herbarium of that genus in this part of the country, certainly the most complete in private possession.

He had been for sometime prior to his death the curator of the Cladoniae herbarium of the Sullivant Moss Society.

He eagerly looked forward to the time when he should be relieved of his other activities sufficiently to permit him to scientifically arrange the material collected and distribute it among those institutions which were interested therein. He had gathered together a library of practically all modern works on the subject, not only in English, but in French and German as well.

For the last eight years he was the chairman of the field committee of the Torrey Botanical Club, and the printed schedules of trips stand out as evidence of his devotion to outdoor botany. They have undoubtedly done much to maintain the tradition established and furthered by John Torrey and Nathaniel L. Britton.

Recognition of his efforts was manifested by his designation as a member of the Board of Managers of the New York Botanical Garden, and his election, this year, to the presidency of the Torrey Botanical Club.

While his work on Cladoniae has permanent scientific value, his efforts in the promotion of outdoor-life and conservation have contributed greatly

not only to the enjoyment of many, but also to the future welfare of this country.

His alert mind and imagination being no doubt attracted by the natural beauty of the New England country-side, he spent much of his time traveling and in fact climbed to most of the important peaks. To facilitate the enjoyment of these natural beauties, he, in co-operation with others, laid out many trails, and particularly did he help in realizing the Appalachian trail from Mt. Katahdin in Maine to Mt. Oglethorpe in Georgia.

Naturally, his particular interest was directed towards the trails in New York City, in which city he spent his entire adult life. At the time of his death he was the chairman of the New York-New Jersey Trail Conference, and he was the editor of the "Guide to the Appalachian Trail," from the Housatonic to the Susquehanna Rivers.

In conjunction with Mr. Frank Place, Jr. and Dr. Robert L. Dickinson he was author of the "New York Walk Book." This publication was well received, and a new edition has been published by Dodd, Mead & Co., in 1934.

Some years prior to his death he gave up newspaper work, in which he had been actively engaged, except "The Long Brown Path," and became the secretary of the American Scenic Historic and Preservation Society and of the Society for the Preservation of the Adirondacks. This work gave him the opportunity, which he had long desired, of effectively advancing the cause of conservation, particularly in the eastern part of the United States. There came under his direct supervision and control such scenic and historic monuments as John Boyd Thacher Park in the Helderbergs, the Stony Point Reservation on the Hudson, Philipse Manor Hall, Letchworth Park, including Portage Falls on the Genesee River, Diamond Island in Lake George, Battle Island Park on Oswego River, and for a time, Watkins Glen in the Finger Lake Region of New York State.

He was above all devoted to the preservation of the Adirondacks, and particularly the lands that constitute the "Forest Preserve" of New York State, which under the State Constitution (Article 7, Section 7) "Shall be forever kept as wild forest lands." By reason of repeated attempts to encroach upon this preserve, Mr. Torrey was kept constantly on the alert in defense of the Forest Preserve. Just before his death, he was particularly concerned, by reason of the fact that a proposed new Constitution was being drawn for the State, and, to him, it was of the utmost importance that present ARTICLE 7 in SECTION 7 should not be thereby impaired or limited in its original scope and intention.

This work of Mr. Torrey's was what gave him the greatest inner satisfaction, since he felt that in protecting our natural heritage from the selfish exploitation by man, he was contributing not only to the preservation and furtherance of the health and spiritual uplift of his contemporaries, but also of those who would come after him, for he had found for himself in this changing and troubled world, in his communion with nature, that salvation for which man ever strives.

In addition to his daily contributions to the newspapers, Mr. Torrey wrote numerous articles of botanical historic, and scenic interest, and especially those concerned with conservation. (See bibliography).

Besides his widow, he left a married son, Raymond, a married daughter, Leonore Torrey Millett, a grandson, Warren Millett, a brother, Warren, of Revere, Massachusetts, and a sister, Mrs. Raymond Jackson, of Greystone Beach, Marblehead, Massachusetts.

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A large species of Rhizophidium from cooked beef

J. S. KARLING
(WITH PLATES 20 AND 21)

In an experiment conducted to determine the host range of several species of *Rhizophidium* which occur on algae, flagellates, rotifers, etc., sterilized bits of ground beef were frequently used as one of the host media. Two of these chytrid species grew fairly well on this medium, and during the course of a study of their thalli a third member of the same genus appeared which at present seems to be different in many respects from any of the known species. With the infected bits of beef as a source of material I have been able to transfer this species to cooked filaments of *Cladophora glomerata*, *Pithophora* sp., *Nitella flexilis*, *Chara coronata* and root tips of *Allium cepa* and *Narcissus* sp. All attempts to grow it on living cells have so far given only negative results. This is the first report in the literature of the occurrence of a species of *Rhizophidium* on cooked ground beef, and such a habitat seems at first to be rather striking and unusual. When it is recalled, however, that other species of the same genus have been reported from dead rotifers, various animal eggs, nematodes, etc., this occurrence appears less remarkable.

The present species is characterized structurally by unusually large thalli, sporangia, zoospores, and resting spores; and with the object of emphasizing these characteristics I am accordingly proposing the specific name *macrosporum* for it.

Rhizophidium macrosporum n. sp. Thalli eucarpic, numerous, gregarious. Zoosporangia hyaline, smooth, predominantly spherical 22–110 μ, oval, broadly pyriform, and urceolate with 1 to 5, usually 2 or 3, low inconspicuous exit papillae. Zoospores spherical 4.5—6 μ, hyaline, with an unusually large, 3–4 μ, clear refractive globule and a 25–35 μ long cilium; occasionally becoming amoeboid; initial swarmspores emerging in a small globular mass surrounded by a hyaline matrix and lying quiescent for a few moments before separating; the remainder becoming active within the sporangium and emerging usually one by one. Rhizoidal system usually extensively developed, coarse, and branched, main axis occasionally 6 μ in diameter; delimited from the sporangia by a cross wall at maturity; arising from a single point or rarely from several places at the base of the sporangium. Resting spores hyaline, smooth, spherical, 15–30 μ, oval, 18×20–33×36 μ, or slightly irregular with a wall 1.5–2 μ thick, and one or more large refractive globules; germination unknown.

Saprophytic on cooked ground beef, dead cells of *Cladophora glomerata*, *Pithophora* sp., *Nitella flexilis*, *Chara coronata* and root tips of *Allium cepa* and *Narcissus* sp., in New York City.

STRUCTURE OF THE THALLUS

The thallus of *R. macrosporum* is usually very large and extensive. Figure 1 shows an exceptionally large individual from cooked beef with a sporangium which measured 105 μ in diameter and whose rhizoidal system extended 310 μ in a linear direction. It is thus obvious from this figure that species of *Rhizophidium* are not always small, but that their thalli may become as extensive as those of *Endochytrium*, *Diplophlyctis*, *Rhizophlyctis*, etc. The rhizoidal system of this species is usually richly branched with the extremities running out to fine tapering filaments and points. It usually arises at one point at the base of the sporangium or resting spores, as is shown in figures 1, 2, 3, 14, 15 and 16, but occasionally several axes may develop at separate regions on the base so that the sporangia become polyrhizoidal, figures 2, 4. Such thalli are doubtless formed from zoospores which develop more than one germ tube, as is suggested by figure 13. Sometimes the rhizoidal system consists of an elongated tapering tubular stalk or axis which branches extensively at its tip, so that the sporangia and resting spores become distinctly stalked, figures 3, 15. This stalk in exceptional cases may attain a diameter of 6 μ. In all thalli which I have been able to observe with clarity on bleached and semi-transparent host material the rhizoidal system was distinctly delimited from the sporangia by a cross wall.

The sporangia are usually sessile, but when they are crowded in groups some may stand off at varying distances from the surface of the host on the rhizoidal stalk. They may vary considerably in size, and as has been noted in the diagnosis given above the largest ones so far found on beef measured 110 μ in diameter. Other spherical ones have been observed on *Cladophora glomerata* and beef which measured only 22 and 23 μ respectively. The majority, however, are much larger according to present observations. Figures 2 and 4 show somewhat urn-shaped sporangia from *Cladophora* and *Chara*, while figure 3 illustrates one from *Nitella*. At maturity the refractive globules are so large and numerous that very little of the remaining protoplasm is visible in the sporangium, as is well shown in figures 1 to 4. The exit papillae are usually rather low and inconspicuous and vary from 1 to 5 in number. Usually only two or three are present and may be located apically or subapically.

The method of zoospore emission is similar to that of other species of *Rhizophidium* with the exception that the initial mass of emerged zoospores is usually rather small, and in the individuals separate and become motile very shortly. One or more of the exit papillae deliquesce at the same time, and a globule of hyaline fluid or slimy matrix issues forth. A few zoospores, 5–10, escape into this globule and lie quiescent for a few

moments. As the globule dissolves in the surrounding water the swarmspores begin to separate and soon dart away. Others emerge successively, pause for a few seconds at the orifice, and then become actively motile. Sometimes the diameter of the orifice, may be smaller than that of the zoospores, so that the latter must elongate to emerge. As the pressure in the sporangium is apparently reduced those within begin to glide upon each other, and in a few seconds thereafter they are swarming violently inside of the sporangium. Those which fail to escape may remain motile for as long as two hours. Eventually they degenerate or germinate in situ. In some cases such trapped zoospores may increase markedly in size before germinating or disintegrating. Figure 9 shows such a zoospores which measured 12 μ in diameter. Its refractive globule has also increased to a diameter of 10 μ. After the zoospores have escaped the sporangia may collapse partly and become greatly wrinkled.

As has been noted above the zoospores are hyaline and spherical, 4.5–6 μ, with a 25–35 μ long posterior cilium. The refringent globule is frequently so large that it appears to constitute the major part of the spore. It is hyaline and refractive, and as the swarmspores become amoeboid and creep about in tight places it may undergo marked changes in shape, figures 6, 7, 8, showing that it is quite plastic in consistency. The motility of the zoospore is typical of other species of this genus. They dart about very quickly, come to rest momentarily, then dash away again. They may occasionally become amoeboid as is shown in figures 6, 7, 8, but this tendency is not as pronounced as in *R. sphaerocarpum*.

Germination of the swarmspores in water is not uncommon as is shown in figures 10, 11, and 13. The germ tube however, is not particularly thick for such large zoospores, according to present observations. Occasionally two and three tubes may develop, and such spores doubtless give rise to polyrhizoidal sporangia and resting spores. During the course of this study another smaller species of *Rhizophidium*, which is to be described below, infected the same host material, and the two were frequently found side by side. Inasmuch as the sporangia were often similar in appearance and the zoospores swarmed together, the suggestion immediately arose that I might be dealing with a heterothallis species with sporangia and motile gametes of marked difference in size. Careful watch was therefore kept for possible conjugation stages. Quite often the zoospores came to rest side by side, figure 13, but no fusion occurred. In other instances the germ tube of the smaller swarmspores was found growing towards the larger one as in figure 12. This suggested the possibility of fusion through a conjugation canal, but from careful observation of a number of such cases I am convinced that this orientation of the

germ tube is merely fortuitous and of no significance sexually. The smaller zoospores doubtless relate to another species.

The development of the sporangia is not fundamentally different from that of other species of *Rhizophidium*, with the exception that the amount of refractive substance is more abundant. This was at first believed to be associated to some degree with the type of host medium used, but since the refractive globules are just as large when the sporangia occur on alga cells this is apparently not a vital factor.

RESTING SPORES

The resting spores of *R. macrosporum* have so far only been found on cooked and degenerating bits of beef. They are hyaline, smooth, predominantly spherical, 15–36 μ, and oval, 18×20 μ–33×37 μ, but occasionally somewhat obpyriform, and irregular ones occur. They usually possess a very large refractive central globule, which in the largest spore so far found measured 30 μ in diameter. The large globule may often be surrounded by a number of smaller ones as is shown in figures 15 to 17. Occasionally two or more fairly large globules may be present, figure 15. The wall is not particularly heavy for spores of this size and does not usually exceed 2 μ in thickness. The spores are predominantly monorhizoidal, but sometimes stalked, figure 15, and polyrhizoidal ones occur, figure 17.

According to present observations these resting spores develop in the same manner as the evanescent zoosporangia up to a certain stage. After that they may usually be recognized by an abundance of large refringent globules as is shown in figure 14. With further development these apparently coalesce to form the large central one which is so characteristic of the mature spores, while the wall begins to thicken. So far no evidence of sexuality has been found in their development, nor has germination been observed.

Rhizophidium sp.—During the course of my study of *R. macrosporum* described above, another species of the same genus was found on dead rotifers, exuviae of various insects, and cysts of several unicellular algae which had been collected in a pond on Dr. R. A. Harper's farm near Ridgewood, N. J. In the shape of its sporangia and size of zoospores it may frequently resemble *R. agile*, *R. gibbosum*, and *Phlyctochytrium bisporum*.

This species was first observed on various dead animal and algal hosts, and with this as a source of material extensive cross inoculation experiments have been made to determine the range of host tissues upon which it will grow. It soon proved to be ubiquitous and capable of infecting and

growing saprophytically on a wide variety of material. Among plants it has been grown on killed cells of *Cladophora glomerata*, *Pithophora* sp., *Oedogonium* sp., *Spirogyra crassa*, *Nitella flexilis*, *Chara coronata*, *Hydrodictyon reticulatum*, and root tips of *Allium cepa*, *Zea mays*, *Pisum sativum*, *Narcissus* sp., *Triticum* sp., and *Avena sativa*. On root tips the thalli occur abundantly over the cap and formative region, and in heavily infected roots as many as 25 sporangia have been counted per sq. mm. of surface.

Among the algal and vegetable debris in which this chytrid occurred were numerous flagellates, rhizopods, rotifers, and other small animals. In the course of time many of these died and became infected. I have accordingly found it growing on dead individuals of *Phacus pleuronectes*, *Euglena viridis*, *Arcella vulgaris*, *Arachnula* sp., *Difflugia urceolata*, *Centropyxis* sp., *Euglypha* sp., *Monostyla* sp., and *Distyla* sp. Its occurrence on such a wide variety of animals suggested at once that it might be grown on other host material of this type. Dead ova and ovarian tissues of *Fasciola hepatica* were added to my cultures and became heavily infected within a few days. In two bits of material the ovarian tissue was completely overrun with thalli. I have also succeeded in growing it on dead eggs and young larvae of *Drosophila melanogaster*, dead abdominal tissues of cockroaches and thoroughly cooked striated muscle cells of beef. Its growth on the latter was limited and sparse, and the thalli did not appear until the beef had degenerated rather thoroughly.

Concurrently with these experiments involving dead plant and animal material attempts were also made to grow this chytrid on living algae and animal tissues. So far the results have been negative so I am inclined to regard this species as a saprophyte. It is to be noted here that Zopf described *R. agile* and *R. gibbosum* as virulent parasites which caused a marked degeneration of the chlorophyll and the remaining protoplasm. In this respect our species differs markedly from those of Zopf.

STRUCTURE OF THE THALLUS

This species is quite gregarious, and as many as 65 thalli have been counted on a single liver fluke ovum. On larger cells such as internodes of *Chara* and *Nitella* several hundred thalli in various stages of development may be present, while on root tips the cap and formative region may sometimes be almost completely covered. When a large number of thalli are grouped together in a localized region on a host cell, as is shown in figure 18, the sporangia are usually small and triangular or irregular in shape, doubtless partly as the result of mutual contact and pressure. Sometimes the sporangia do not rest directly on the surface of the host

cell but stand off at varying distances on the rhizoidal stalk or axis. In a few instances this extramatrical stalk has measured 10 to 15 μ in length.

This size to which the thallus may grow is illustrated in figure 19 of an isolated specimen growing on a thin, almost transparent strip of ovarian tissue of *Fasciola hepatica*. The rhizoidal system extended for a linear distance of 197 μ and consisted of a long stalk, 4 μ in diameter, which branched several times at its lower extremity. The sporangium measured 45 μ in diameter and is almost spherical in shape, with eleven exit papillae distributed rather evenly over its surface. This is one of the largest specimens I have so far found, and may be regarded as representing the upper limits. The lower limit in size is shown in figure 20. This sporangium is only 12 μ in diameter, while the rhizoidal system extends only about 25 μ in linear direction.

The main axis or stalk of the rhizoidal system when present may vary considerably in diameter and length. Occasionally it may be short, inflated, and apophysis-like, as in figures 21 and 31. When the thallus shown in figure 21 was first observed on *Narcissus* root tips I believed it related to a species of *Phlyctochytrium*, but as I followed it through to maturation and the emission of its zoospore I became convinced that it belonged to *Rhizophidium* sp. Such thalli according to present observations are comparatively rare, but they none the less show that species of *Rhizophidium* may occasionally resemble members of *Phlyctochytrium* in the character of the intramatrical rhizoidal system. A few thalli of this nature with small intramatrical, apophysis-like swellings on the rhizoidal system have also been reported by Zopf (1888, pl. 20, fig. 19) and Morini (1896, fig. 2) for *R. gibbosum* and *R. messanense* respectively.

The central stalk or axis may often be very short or lacking entirely, and in such cases a number of rhizoidal branches arise at the base of the sporangium as is shown in figures 24 and 30. These branches may often be very fine in the small thalli so as to form a brush-like tuft, while in the larger ones they may be relatively coarse.

The mature sporangia also vary considerably in shape and size. They may be almost spherical, 10–52 μ, slightly depressed, wedge-shaped and somewhat triangular, $14\times29\ \mu$–$25\times30\ \mu$, oval and occasionally slightly irregular. The exit papillae are usually very low and vary from 1 to 11 in number. Sporangia with a single papilla as well as those with a high number are comparatively rare. Two to four appear to be the most common numbers according to present observations. The highest number of papillae usually but not always occur on the larger sporangia. The orifices for the emission of the zoospores vary from 3 to 5 μ in diameter and are usually slightly oval or spherical.

In mounting the host tissue for study sporangia often break away from the rhizoidal system and lie free in the surrounding water. Occasionally the main rhizoidal axis or stalk accompanies them, figure 33. These sporangia are quite normal in appearance, and if mature they may undergo cleavage and emit their zoospores in the usual manner. Their ability to break away and develop thus is doubtless due to the fact that they are delimited from the rhizoidal system by a cross wall.

At maturity the protoplasm of the sporangia is relatively homogeneous optically, except for a great number of minute globules which do not appear to be refringent as those of other *Rhizophidium* species. This difference may be due largely to their small size, since they usually measure less than 1 μ in diameter. Figure 22 shows the appearance of a sporangium with two subapical exit papillae approximately two hours before dehiscence began. Whether or not cleavage has occurred is not certain, but the limits of the individual zoospores are not yet visible. A short while before the sporangium opens, however, the lines of demarcation usually become quite distinct. Often the distinction may become as clear and sharp as Couch (figs. 59, 60) has shown in *P. bisporum*. Since the thalli occur in such great abundance it is not difficult to find sporangia in all stages of dehiscence. Several exit papillae may deliquesce at the same time, so that the swarmspores may be seen emerging at several places on the sporangium. Sometimes they emerge one by one, become momentarily amoeboid and swim directly away, figure 23. In other cases a number of spores may emerge in a small globular mass surrounded by a hyaline matrix and lie quiescent for a few moments before loosening up and moving apart, figure 24. From present observations I believe the latter type of behavior is the more normal and usual for the very large sporangia of this species. Numerous factors, however, such as unfavorable environmental conditions, premature deliquescence of the exit papillae etc., undoubtedly influence the process and lead to variations. I have not so far observed the initial globular mass of extruded zoospores to become as large and conspicuous as Zopf describes for *R. sphaerocarpum*. This may perhaps be due in part to a difference in viscidity of the surrounding matrix. After a considerable number of zoospores have emerged the pressure in the sporangium is apparently reduced, so that the remaining spores soon become active. They first begin to glide slowly upon each other, but after a few seconds they attain such motility that the sporangium becomes a mass of seething and darting spores. These then emerge one by one, in twos, or in threes. By observing only this stage one might readily get the impression that it constitutes an initial stage of zoospore emission. The length of time required for total emission is rather short, varying from

50 to 200 seconds, according to the size of the sporangium. Occasionally a number of zoospores may fail to escape and these either degenerate or germinate in situ. The empty sporangium usually becomes somewhat shriveled and wrinkled, and may often take on a yellowish brown tinge with age. Extensive tests with chloroiodide of zinc on the walls have so far failed to give any cellulose reaction. This is in marked contrast to *R. agile*, whose sporangial walls Zopf describes as being composed of cellulose.

The zoospores, figure 26, are hyaline, spherical, 2.5–3 μ in diameter with a small refractive globule usually lying in the posterior region. The cilium is approximately 25 μ in length. The swarmspores dart about with great rapidity, and may remain actively motile for more than half an hour. They may occasionally become amoeboid, figure 25, but this is not nearly as marked as in *R. sphaerocarpum*. Germination occurs quite frequently in water, figures 27–29, and often more than one germ tube may develop. During germination the zoospore becomes vacuolated, and the refractive globule is thus displaced towards the periphery, figure 29.

The further development of the thallus is fundamentally similar to that of other species of *Rhizophidium*. After the germ tube has branched to form the rudiments of the rhizoidal system, and the latter has become somewhat extended, the zoospore begins to enlarge into an incipient sporangium. Figure 30 shows a very early stage in which the young spo-

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Explanation of Plate 20

Rhizophidium macrosporum n. sp.

Fig. 1. A large thallus from cooked beef with an extended rhizoidal system and a spherical zoosporangium filled with large refractive globules.

Fig. 2. Smaller urn-shaped sporangium with three exit papillae and two main rhizoidal axes.

Fig. 3. A stalked sporangium with four exit papillae.

Fig. 4. A small sporangium with three separated rhizoidal axes.

Fig. 5. A zoospore showing the unusually large refractive globule.

Figs. 6–8. Amoeboid zoospores showing the changes in shape undergone by the refractive globule during amoeboid movement.

Fig. 9. A quiescent, greatly expanded zoospore which failed to emerge from the sporangium.

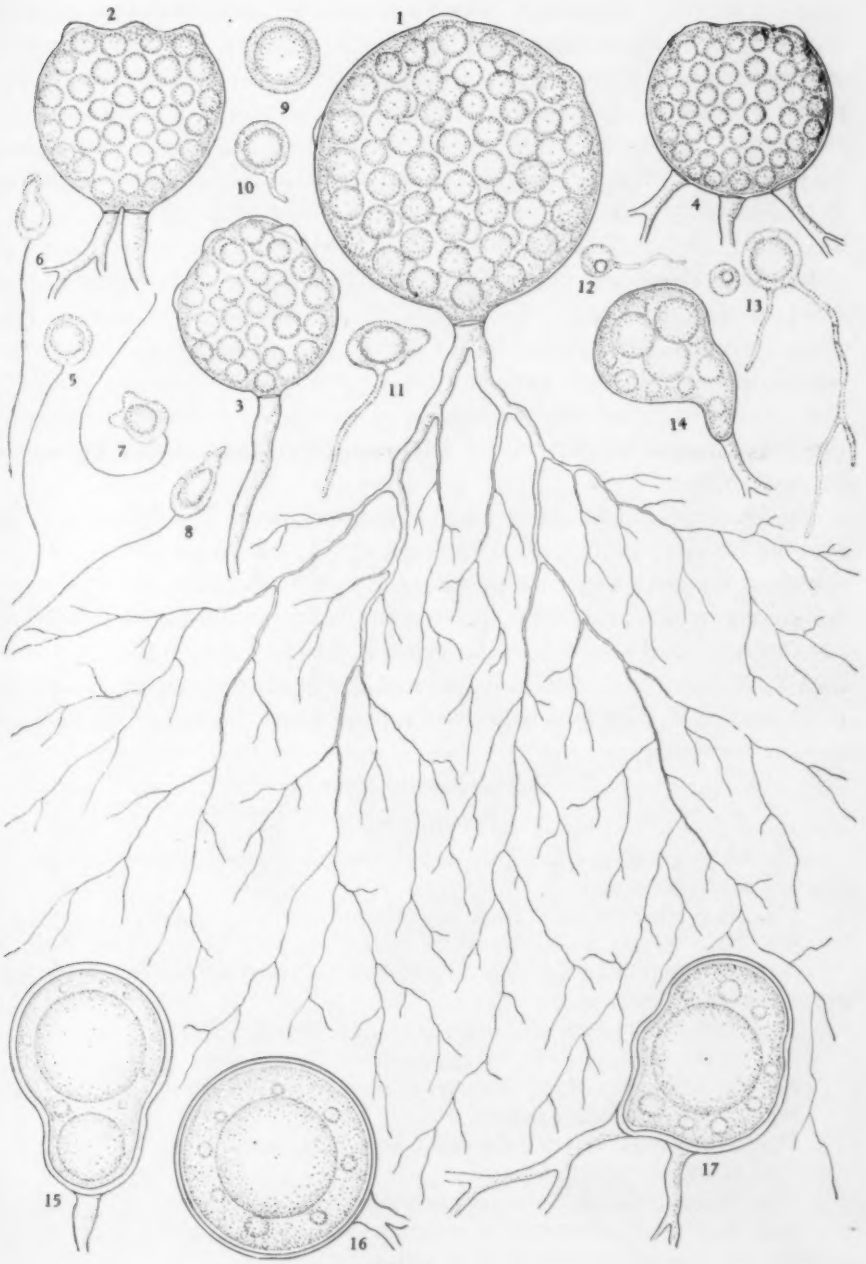
Figs. 10,11. Early germination stages.

Fig. 12. Germination of a zoospore of *Rhizophidium* sp., with the germ tube directed towards a swarmspore of *R. macrosporum*.

Fig. 13. A zoospore of *Rhizophidium* sp. lying close to a germinating swarmspore of *R. macrosporum*.

Fig. 14. An early stage of resting spore development.

Figs. 15–17. Variations in the size and shape of the resting spores.



KARLING: RHIZOPHIDIUM

rangium is quite vacuolated. This condition appears to be characteristic of the early developmental stages, as Couch (figs. 54, 55) has shown for *P. bisporum* also. Furthermore, the remainder of the protoplasm is rather pearly opaque and not as refringent as I have observed it in other species. In figure 31 is shown a half grown sporangium with three conspicuous vacuoles. One of them contains a dark globule which showed striking Brownian movement. This sporangium was kept under observation for a long time, and during this period the three vacuoles were continually changing in shape and position, indicating a definite circulation or movement of the protoplasm. Eventually these vacuoles fused into a large central one, as is illustrated in the sporangium of figure 32. As the sporangia increase in size and mature the vacuolate condition gradually disappears. The movement and fusion of the vacuoles described above are the only unusual characteristics I have observed in the development of the sporangia.

As has been stated above no resting spores were found on any of the host material employed. In two instances a light brown, thick-walled, spherical, 9 μ resting spore with a large, 5 μ refringent globule in the center and a long hyaline, attached, haustorium-like peg was observed, but I am not certain that it relates to our species. It is to be noted in this connection that Zopf and Couch also failed to find the resting spores of *R. agile*, *R. gibbosum* and *P. bisporum* in spite of repeated search over a long period of

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Explanation of Plate 21

Rhizophidium sp.

Fig. 18. A group of stalked, somewhat triangular-shaped sporangia on the surface of a liver fluke ovum.

Fig. 19. A large thallus on the ovarian tissue of *Hepatica fasciola*.

Fig. 20. A minute thallus drawn for comparison with the one shown in fig. 19.

Fig. 21. A portion of a thallus from root tips of *Narcissus* showing the inflated, apophysis-like rhizoidal stalk.

Fig. 22. A sporangium with two exit papillae shortly before cleavage.

Fig. 23. An initial stage in the emergence of the zoospores.

Fig. 24. Emergence of the zoospores from a large sporangium.

Fig. 25. An amoeboid zoospore.

Fig. 26. A zoospore during the active swimming stage.

Figs. 27–29. Germination stages.

Figs. 30–32. Stages in the development of the zoosporangium.

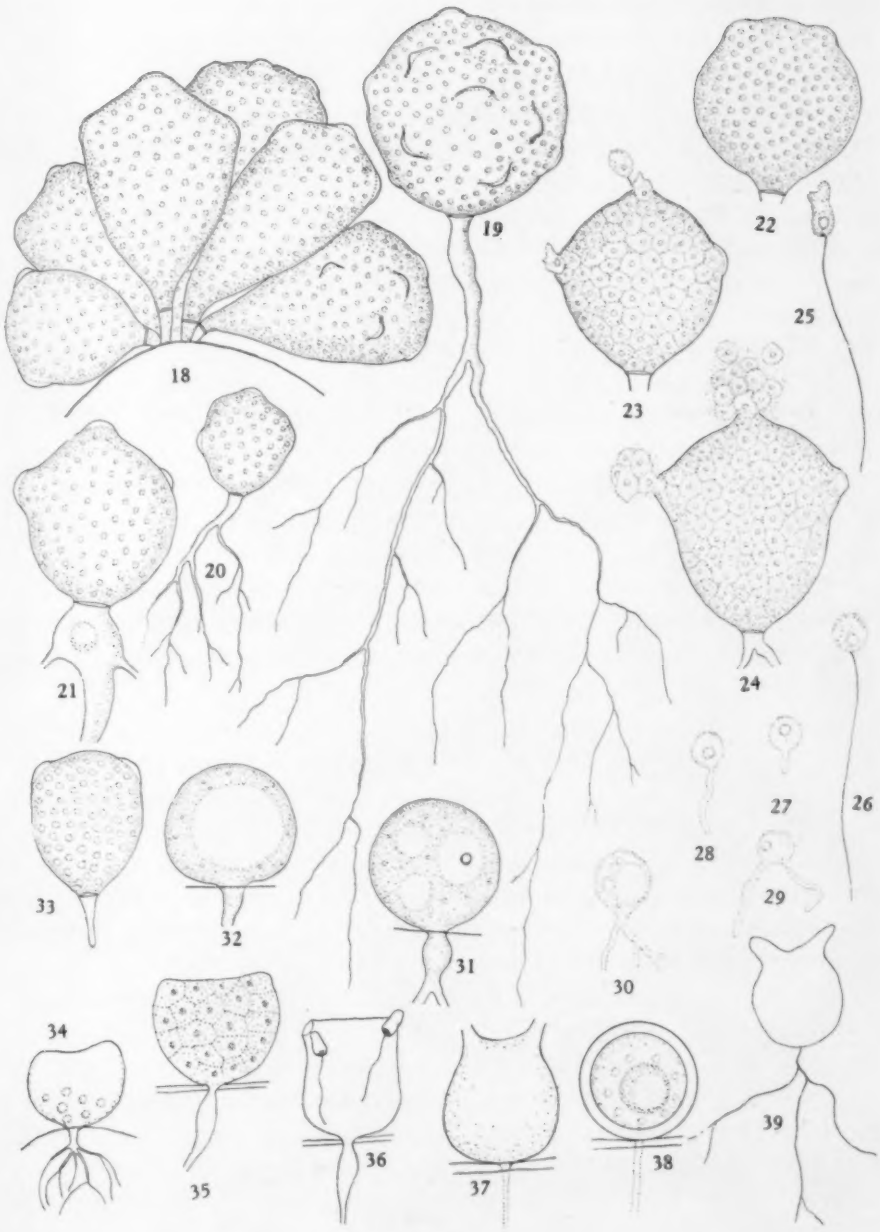
Fig. 33. A small free-floating sporangium with two exit papillae.

Fig. 34. A small sporangium of *R. agile* after Zopf.

Figs. 35, 36. Sporangia of *Phlyctochytrium bisporum* after Couch.

Figs. 37, 38. A sporangium and resting spore of *P. bisporum* after Sparrow.

Fig. 39. A thallus of *R. rostellatum* after de Wildeman.



KARLING: RHIZOPHIDIUM

time. Whether or not this may indicate a possible relationship or identity of these species with ours is of course a matter of speculation.

DISCUSSION

As has been noted above the small sporangia of *Rhizophidium* sp. frequently bears considerable resemblance to those of *R. agile*, *R. gibbosum*, *R. rostellatum*, and *Phlyctochytrium bisporum*. With the view of presenting these similarities more concisely I have brought together in figures 34 to 39 thalli of these species as they have been illustrated by Zopf, Couch, Sparrow and de Wildeman. This is, of course, a selected group of drawings and shows only the thalli which are similar as to shape. *Rhizophidium agile* was described by Zopf (1888) and Serbinow (1907) on *Chroococcus turgida*, and is characterized by small, 10–15 μ, slightly triangular sporangia with an apical exit papilla, minute, 2.5 μ, zoospores, and a virulently parasitic nature. The smallest sporangia of our species fall within the size magnitude of those of *R. agile*, but the largest ones may be five times as great in diameter. Furthermore, as many as 11 exit papillae may occasionally be present on such sporangia, giving them a distinct gibbose appearance. In this respect they may frequently resemble some of the sporangia of *R. gibbosum* Zopf (1888) on species of *Cylindrocystis*, *Phycastrum* and *Penium*. The zoospores of *R. gibbosum* are similar to those of our species in size, behavior, and general appearance, but the sporangia have only a single functional apical papilla, according to Zopf.

The sporangia, zoospores and rhizoidal system of our species are also often very similar to those of *Phlyctochytrium bisporum* described by Couch (1932) and Sparrow (1933, 1936) on *Vaucheria*, *Oedogonium*, *Bumilleria* and *Spirogyra*. This species is characterized by small, 8–13 μ, sporangia with two exit papillae or orifices near the apex which give them a somewhat triangular shape, figures 35–37, an occasionally inflated rhizoidal stalk, and zoospores which measure 2.6–3 μ in diameter. A comparison of Couch's and Sparrow's drawings with my figures 18, 22, 23, 24 and 33 show a striking similarity in shape relative to the smaller sporangia. A further similarity is suggested by Couch's report that his species usually grows on the disorganized cells of the host, which indicates that it may be largely saprophytic. Couch failed to observe the resting spores, but Sparrow (1936) found hyaline, spherical, thick-walled spores, figure 38, associated with the sporangia which he believes may belong to *P. bisporum*. He further believes that Couch's species is the same as *R. rotellatum* (de Wildeman) Fischer which occurs on *Spirogyra crassa*. Figure 39 shows a thallus of the latter species as drawn by de Wildeman and in the presence of the two horn-like exit papillae it is very similar to Sparrow's drawing, figure 37, of *P. bisporum*.

The occasional similarities in size and shape of the sporangia and zoospores of our chytrid with those listed above may indicate a close relationship of these species, but until more is known about them, it is impossible to determine whether or not they are identical. Characters such as size and appearance of sporangia, number of exit papillae, etc., are often highly variable and, within certain limits, of doubtful diagnostic value, so that too much significance must not be attached to them. Accordingly, in view of the fact that I have so far failed to find the resting spores in *Rhizophidium* sp., I shall for the time being leave it unidentified. I am none the less continuing my study on it with the hopes of observing its complete life cycle.

The present study shows how ubiquitous and large species of *Rhizophidium* may be. The majority of species are described in the literature as being comparatively small and parasitic or weakly saprophytic. *Rhizophidium macrosporum* and *Rhizophidium* sp., appear at present to be primarily saprophytic and capable of growing on a wide variety of dead animal and plant tissues. Furthermore, in the former species the thalli may attain the size of species of *Entophlyctis*, *Endochytrium*, *Diplophlyctis*, etc. Doubtless as more intensive studies of individual species are made, we shall find an even greater variability in size and host range.

SUMMARY

Rhizophidium macrosporum was first observed on cooked ground beef, and has subsequently been grown on various sterilized filamentous algae and root tips. It is characterized by large spherical (22–110 μ) oval and broadly pyriform, hyaline, smooth sporangia, spherical (4.5–6 μ) zoospores with an unusually large refractive globule, a coarse extensive rhizoidal system, and large spherical (15–30 μ) or oval (18×20–22×37 μ) hyaline resting spores.

Rhizophidium sp. occurs saprophytically on a wide variety of dead filamentous and unicellular algae, flagellates, rhizopods, rotifers, liver fluke ova and ovarian tissue, eggs, larvae and exuviae of insects, cooked striated muscle cells and root tips of various plants. The sporangia may be almost spherical (10–52 μ), slightly depressed, wedge-shaped and somewhat triangular (14×29 μ–25×30 μ) oval and occasionally slightly irregular with 1 to 11 exit papillae. The smaller sporangia may often resemble those of *R. agile*, *R. gibbosum*, *R. rostellatum* and *Phlyctochytrium bisporum*. Resting spores have so far not been found.

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Thiamin and growth of Pythium Butleri

WILLIAM J. ROBBINS AND FREDERICK KAVANAGH
(WITH THREE FIGURES)

Studies on the relation of thiamin (vitamin B_1) to the growth of fungi have shown that on the basis of our present knowledge they may be arranged in at least three groups.

GROUP I includes those which synthesize thiamin from the elementary materials of the medium and require for growth no external supply of thiamin or its intermediates. The growth of some of these plants is not materially affected by the addition of thiamin to the medium; that of others is inhibited by its addition (3).

GROUP II includes those which do not synthesize thiamin or its intermediates from the constituents of the medium. Some of these are incapable of forming thiamin from the thiazole and pyrimidine intermediates; for growth to occur they require an external supply of the vitamin as such (4, 5). Others are capable of forming the vitamin from the intermediate thiazole and pyrimidine, but are incapable of synthesizing the intermediates themselves. These plants require for growth an external supply of thiamin or of both intermediates (2, 7, 8, 9).

GROUP III includes those which do not synthesize thiamin but are able to form one or the other of the vitamin intermediates. Some form pyrimidine; these grow if furnished with thiamin or with the vitamin thiazole (1); others form thiazole and grow if supplied with thiamin or the vitamin pyrimidine (3, 10).

Pythium Butleri Subramanian differs somewhat from all the types described above. Under certain conditions this organism appears to form thiamin but in amounts inadequate for maximum growth; under other conditions it forms little or no thiamin. In either instance the addition of thiamin or of pyrimidine increases the rate of growth. In its ability to grow in media containing no growth supplement it resembles the organisms of GROUP I; in its response to thiamin and pyrimidine, the organisms of GROUP III.

METHODS AND MATERIALS

The culture of *Pythium Butleri* was furnished by J. T. Middleton. Stock cultures were maintained on potato dextrose agar.

Several nutrient solutions were used as follows:

SOLUTION D, containing about 16.4 g. of salts per liter, was composed of $MgSO_4 \cdot 7H_2O$, 5.0 g.; KH_2PO_4, 10.32 g.; Na_2HPO_4, 0.575 g.; NH_4NO_3, 0.5.; asparagine, 5.0 g.: dextrose (cerelose), 50.0 g. and redistilled water, 1000 cc. To each liter of the above solution 1 ml. of a modified Hoagland's

A to Z mixture (3) was added. The hydrion concentration was pH 5.5.

SOLUTION E, containing about 1.64 g. of salts per liter, was made by diluting the salts and asparagine of solution D ten times and reducing the dextrose to 20 g. per liter.

SOLUTION G, containing about 1.64 g. of salts per liter, was made by diluting the salts of solution D ten times but maintaining the asparagine and dextrose concentrations unchanged.

SOLUTION I contained no organic nitrogen. It was composed of $MgSO_4 \cdot 7H_2O$, 0.25 g.; KH_2PO_4, 0.5 g.; NH_4NO_3, 1.0 g.; KNO_3, 1.0 g.; dextrose, 25.0 g. and redistilled water 1000 cc. To each liter of this solution 1 ml. of a mixture of Steinberg's mineral supplements (4) was added.

The thiamin chloride used was a crystalline product (betabion) from Merck and Co. The thiamin intermediates, supplied through the courtesy of Merck and Co., were 2-methyl-5-bromomethyl-6-amino pyrimidine hydrobromide, 2 methyl-5-ethoxymethyl-6-amino pyrimidine, and 4-methyl-5β-hydroxyethyl thiazole. For brevity the first mentioned pyrimidine and the thiazole are referred to in this paper as pyrimidine and thiazole respectively.

The asparagine was repurified by solution in water and precipitation with alcohol for all experiments except those with solution D. The dextrose was a sample of high purity (cerelose) from the Corn Products Co.

The solutions were sterilized at 12 lbs. pressure for 20 minutes. In some instances the thiamin was filtered sterile and added to the basic nutrient solutions which had been sterilized by heating.

The *Pythium* was grown at room temperature (20–25°C) in 25 ml. of solution in 125 ml. flasks of pyrex glass. The solution in the flask was inoculated by transferring a bit of mycelium from the stock cultures. In making inoculations care was used to avoid transferring any of the medium in which the inoculum had grown. All cultures were grown in triplicate.

Dry weights were determined by washing the mycelium with water to remove the sugar and drying at 100°C. Some difficulty was experienced in washing the mycelium free of sugar, and the dry weights in the earlier experiments were influenced to some extent by residual sugar.

EXPERIMENTAL

SOLUTION D.—*P. Butleri* grew very poorly in solution D forming but 4 mg. of dry mycelium in 19 days. The addition of 3 units[1] or 30 units of thiamin increased the growth more than 70 times (table 1). The addition of thiazole alone had little effect but pyrimidine alone was quite effective. A mixture of thiazole and pyrmidine increased growth but much less

[1] A unit is 10^{-9} Mole of the compound.

than molecularly equivalent amounts of thiamin. The effects of supplementing solution D with thiamin or its intermediates on the growth of *P. Butleri* are shown in figure 1.

We are uncertain as to how much reliance should be placed on the differences in dry weights in the solutions supplemented with thiamin, pyrimidine and the mixtures of thiazole and pyrimidine. It would seem from the photographs taken at the end of 14 days incubation (fig. 1) and the dry weights determined after 19 days growth (table 1) that thiamin

TABLE 1

Dry weight of mycelium of Pythium Butleri grown 19 days in solution D, 14 days in solution G or 19 days in solution I and in the same solutions supplemented with thiamin or its intermediates

SUPPLEMENT	DRY WT. MG. MYCELIUM SOLUTION D	DRY WT. MG. MYCELIUM SOLUTION G	SUPPLEMENT	DRY WT. MG. MYCELIUM SOLUTION I
None	4	149±21	None	39±4
3 units thiamin	285±15	168±10	5 units thiamin	110±4
30 units thiamin	305±5	210±3	5 units thiazole	73±9
3 units thiazole	13	169	5 units pyrimidine	103±3
30 units thiazole	26±33	180±4	5 units thiazole and 5 units pyrimidine	94±9
3 units pyrimidine	249±32	236±11	dextrose only no salts	0.6
30 units pyrimidine	230±25	293±7		
3 units thiazole and 3 units pyrimidine	23	266±27		
30 units thiazole and 30 units pyrimidine	135±15	305±10		

was more effective in solution D than either pyrimidine alone or the mixture of thiazole and pyrimidine. It would appear also that the mixture of thiazole and pyrmidine was less effective than molecularly equivalent quantities of pyrimidine. Before such conclusions can be drawn additional experiments with solution D should be performed; uniformity in inoculations with this organism is difficult to secure. Furthermore, the time factor is important as may be noted by comparing the relative growth of the fungus in the solutions supplemented with thiamin and its intermediates as shown in the photograph taken after 14 days growth and the relative dry weights formed at the end of 19 days. In any event the beneficial

effect of the additions of thiamin and of pyrimidine to the medium were clear.

During the course of this experiment the growth in one of the flasks supplemented with 3 units of pyrimidine was observed to be considerably heavier than that in the other two. Microscopic examination showed contamination by a rod shaped bacterium in this flask. It is probable that thiamin formed by the contaminating organism was responsible for the more rapid growth of *Pythium* in the contaminated culture (fig. 2).

Fig. 1. Growth of *Pythium Butleri* in solutions supplemented with thiamin or its intermediates. Above, solution D with 3 units of supplements; center, solution D with 30 units of supplements; below, solution E with 30 units of supplements. In each series from left to right; no supplement, thiamin, thiazole, pyrimidine, thiazole and pyrimidine. Period of growth 14 days.

It would seem from the results with solution D that *P. Butleri* belongs with those organisms described above in GROUP III which grew satisfactorily with the addition to the basic medium of either thiamin or the intermediate pyrimidine. However, when solution D was diluted differences in the response of this fungus and those mentioned earlier became apparent.

SOLUTION E.—*P. Butleri* grew in solution E without the addition of any supplement (fig. 1). In 19 days it formed 45 mg. of dry mycelium under the same conditions in which it formed but 4 mg. in solution D. To eliminate the possibility that this growth was made at the expense of

thiamin carried over in the inoculum a subculture was made from the growth in solution E to a fresh lot of the same solution. In 19 days mycelium of 68 mg. dry weight was produced. A third transfer yielded 76 mg. in 14 days. *P. Butleri* appeared to be capable of growing indefinitely in a suitable solution to which no supplement had been added.

The addition of 3 units or of 30 units of thiamin to solution E increased the growth, the effect showing more sharply in the early stages of development than later. However, much less mycelium developed in solution E in the presence of thiamin than in solution D, which was taken to indicate that some factor (probably the nitrogen content) limited growth in the former medium. To obviate this difficulty solution G was used.

Fig. 2. Effect of contaminating bacteria on growth of *P. Butleri* in solution D plus 3 units pyrimidine. Left, uncontaminated; right, contaminated. Period of growth 14 days.

SOLUTION G.—In this solution (table 1) *P. Butleri* formed 149 mg. of dry mycelium in 14 days. The addition to solution G of thiamin, of pyrimidine, or of the mixture of thiazole and pyrimidine increased the growth. Thiazole alone had little effect. From three to four times as much mycelium was formed in solution G as was produced in the same time in solution E. This was interpreted to be the result of the greater amount of asparagine and dextrose furnished in solution G.

Solutions D, E, and G contained asparagine which is an organic substance of natural origin. In order to eliminate the asparagine as a complicating factor a solution was used containing no nitrogen other than inorganic nitrogen.

SOLUTION I.—*P. Butleri* grew slowly in solution I forming a mycelium

of 39 mg. in 19 days. A subculture from this solution to more of the same medium yielded 120 mg. in 26 days; a third, fourth and fifth successive transfer to solution I was made with no evident diminution in the rate

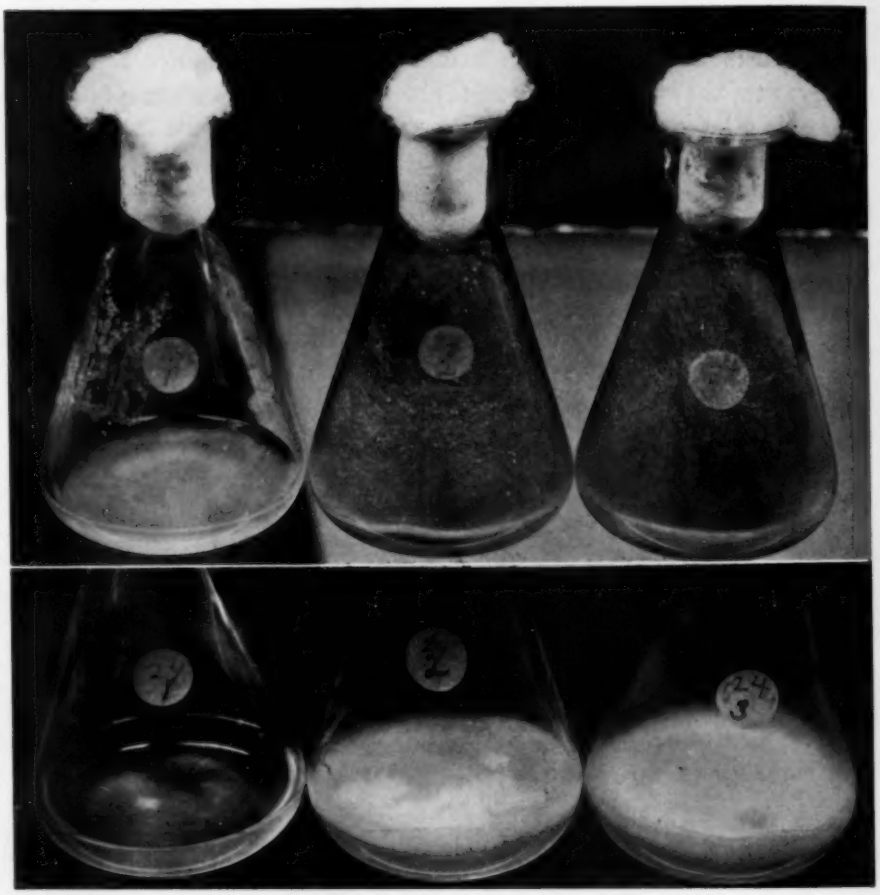

Fig. 3. Formation of thiazole by *P. Butleri*. Below from left to right, solution D plus thiazole, plus pyrimidine, plus thiazole and pyrimidine. Above, same solutions sterilized, mycelium removed and inoculated with *Phycomyces Blakesleeanus*.

of growth. These results indicate that this fungus is capable of unlimited growth in a mineral solution containing dextrose.

The addition of thiamin, of ethoxypyrimidine or of thiazole and pyrimidine to solution I increased the growth of *P. Butleri* (table 1), each of the compounds or combination of compounds being nearly equally effective. Thiazole produced a small increase.

Formation of thiamin and intermediates by P. Butleri.—The results

given above show that the growth of *P. Butleri* in the solutions used was improved by the addition of thiamin or of pyrimidine. The effect of thiazole was less marked. How should these results be interpreted? Does the fungus require thiamin forming some, though insufficient for maximum growth, in the unsupplemented solutions and synthesizing thiazole in the solutions supplemented with pyrimidine? Or does it require pyrimidine only, synthesizing small quantities in the unsupplemented solutions and securing the necessary amount in the thiamin cultures by splitting the vitamin into its thizaole and pyrimidine constituents? We have no direct evidence to show the need for thiamin as such, though we are inclined to believe that the organism requires the vitamin rather than the intermediates. We have evidence, however, that in the thiazole solutions *P. Butleri* forms some pyrimidine and in the pyrimidine cultures it forms considerable thiazole. In other words. *P. Butleri* requires both intermediates for growth forming thiazole more readily than pyrimidine. The evidence upon which this conclusion is based is as follows:

P. Butleri was grown in solution D supplemented with 30 units of thiazole, 30 units of pyrimidine or 30 units of both intermediates. The growth in the thiazole solutions was slight; it was considerably heavier in the solutions containing pyrimidine or both intermediates (see fig. 3). At the end of 19 days the mycelium of *P. Butleri* was removed, the solutions sterilized and inoculated with *Phycomyces Blakesleeanus*. This fungus has been demonstrated to require for growth an external supply of thiamin or of both intermediates. At the end of twelve days *Phycomyces* had produced some submersed mycelium in the solution originally supplemented with thiazole only, indicating the formation of a small quantity of pyrimidine. In the solution originally supplemented with pyrimidine only there was a heavy development of aerial mycelium with sporangia and sporangiophores showing the formation of 3 units of thizaole or more. These results indicate that *P. Butleri* requires both intermediates for growth and synthesizes more thiazole than pyrimidine.

DISCUSSION

We have interpreted the results of the experiments described above to mean that *P. Butleri* requires thiamin for growth, in the more dilute solutions used (solutions E, G and I) the fungus synthesized from the more elementary constituents of the medium sufficient vitamin for slow growth but insufficient for maximum growth. In other words, in these solutions the amount of thiamin formed by the organism was the factor limiting growth. Judging from the effect when pyrimidine alone was used as a supplement it would seem that a slow formation by the organism of

the pyrimidine portion of the vitamin molecule was the limiting factor in solutions E, G, and I.

On the basis of the above interpretation we would explain the failure of *P. Butleri* to grow in solution D as follows: In this solution the total salt concentration or concentration of some particular salt interferred with the synthesis of thiamin. The assumption that the salt concentration interferred with thiamin synthesis rather than the functioning of the vitamin would seem to follow since the addition of thiamin to solution D markedly improved the growth; it was effective if present. We cannot say definitely whether the salt concentration interferred with the synthesis of the intermediates by *P. Butleri* or the synthesis of thiamin from the intermediates. The latter would be suggested by the relatively poorer growth in the solution D supplemented with thiazole and pyrimidine than in the same solution supplemented with thiamin. This difference did not appear in the more dilute solutions (solutions G and I, table 1). However, the salt concentration appeared to interfere with the formation of the pyrimidine portion of the vitamin more than it did with the thiazole portion. This follows because growth in solution D supplemented with thiazole alone was much less, relative to that in the same solution supplemented with thiamin or with pyrimidine, than in the more dilute solution G (table 1).

The beneficial effect on the growth of *P. Butleri* of the dilution of solution D and of the addition of thiamin to the same solution is similar to the results reported by Seager (6) for *Lemna*. Seager observed that *Lemna* did not grow indefinitely in Knop's solution. The addition of dried yeast to Knop's solution or the dilution of the solution to 1/10 its normal strength permitted growth to occur, although even in the dilute Knop's solution the addition of yeast was beneficial.

The response of *P. Butleri* to thiamin and its intermediates is of particular interest because it shows that salt concentrations may injure a plant because of its effect upon thiamin production. Why should this be true of *P. Butleri* and not of *Aspergillus niger* which grows well in solution D? Furthermore, other organisms which have been reported incapable of synthesizing thiamin should be tested in various solutions and conditions since the formation of thiamin by *P. Butleri* was influenced by the conditions (mineral salt concentration) of culture.

SUMMARY

The growth of *Pythium Butleri* in a mineral salt solution containing asparagine and sugar (solution D) was negligible. The addition of thiamin or the vitamin pyrimidine markedly increased the growth.

P. Butleri was capable of unlimited growth when the salts of solution D were diluted; growth was increased in this solution by the addition of thiamin or pyrimidine.

Contaminating bacteria in one instance increased growth of *P. Butleri*.

The formation of thiazole and of smaller amounts of pyrimidine was demonstrated.

It is concluded that under the conditions of these experiments the growth of *P. Butleri* was limited by its thiamin production which was affected by the concentration of salts in the solution.

THE NEW YORK BOTANICAL GARDEN

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Studies in the American Celastraceae I. New species of Microtropis, Wimmeria and Zinowiewia[1]

C. L. Lundell
(with three figures)

In studies of the Mexican and Central American flora, particularly that of the Maya area, the need for a systematic study of the Celastraceae has interested the writer. Through a preliminary series of revisions of the genera of American Celastraceae, it is hoped that interest of collectors will be stimulated so that material of many of the lesser known genera and species can be accumulated to make possible later an adequate monographic treatment of the family. As illustrated by the situation in the genus *Zinowiewia*, many of the celastraceous species are poorly represented in herbaria, all too many being known from a single collection. That many interesting forms remain to be discovered is evident; no less than four of the new species of *Zinowiewia* were collected for the first time between 1933 and 1937.

Included in this paper are nine new species which represent undescribed forms discovered in revising the American species of *Microtropis*, and the genera *Wimmeria* and *Zinowiewia*.

In the list of citations of herbarium specimens, the following abbreviations of the names of herbaria are employed:

A—Arnold Arboretum, Jamaica Plain, Mass.
D—Dudley Herbarium, Stanford University, Calif.
F—Field Museum of Natural History, Chicago, Ill.
G—Gray Herbarium, Harvard University, Cambridge, Mass.
K—Royal Botanic Gardens, Kew, Surrey, England
M—University of Michigan, Ann Arbor, Mich.
Mo—Missouri Botanical Garden, St. Louis, Mo.
NY—New York Botanical Garden, New York, N. Y.
P—Academy of Natural Sciences, Philadelphia, Pa.
US—United States National Herbarium, Washington, D. C.

The writer is deeply indebted to the directors and curators of these institutions for their courtesy in making the material available. All of the cited specimens have been uniformly annotated with printed labels.

Microtropis Standleyi sp. nov.—Frutex epiphyticus, 2-metralis. Folia 5–8 mm. longe petiolata, chartacea, discolora, lanceolato-elliptica vel oblongo-elliptica, 5.5–9.5 cm. longa, 1.8–3.8 cm. lata, apice breviter acuminata, acumine obtusiusculo, basi cuneata vel acutiuscula. Cymae 2.3 cm. longae vel minores. Flores masculi virides. Sepala inaequalia, suborbicularia vel late

[1] Papers from the Herbarium of the University of Michigan.

ovato-orbicularia, 2 exteriora 1.2–1.4 mm. lata, interiora 1.5–2.2 mm. lata, margine minute erosa. Petala late obovata vel suborbicularia, 2–2.4 mm. longa, margine minute erosa. Discus pentagonus, crassus, ca. 1.8 mm. diam. Filamenta ca. 1 mm. longa. Antherae late cordatae, ca. 0.5 mm. longae. Ovarium in discum subimmersum. Flores femineos non vidi. Fructus ignotus.

An epiphytic shrub about 2 m. high, not scandent; branchlets usually opposite, rather slender, striate, drying reddish-black. Leaves chartaceous, paler beneath, margin entire, slightly revolute. Petioles canaliculate, 5 to 8 mm. long. Leaf blades lanceolate-elliptic or oblong-elliptic, 5.5 to 9.5 cm. long, 1.8 to 3.8 cm. wide, apex short acuminate, the acumen obtusish, base cuneate or acutish, costa prominent beneath, prominulous above, main lateral veins 4 or 5 on each side, strongly ascending from base, arcuately ascending from medial region, prominulous beneath, fainter above, veinlets inconspicuous. Cymes 2.3 cm. long or less, divaricately forked 3 to 5 times, each node bibracteate; peduncles stout, 3.5 to 7.5 mm. long; primary branches 2 to 4 mm. long; ultimate branches shorter. Bracts and bractlets semicymbiform, 1 to 1.5 mm. long, margin minutely erose, reddish. Staminate flowers green or pale green, pentamerous or tetramerous (excepting ovary), subsessile or with a very short thick pedicel. Sepals strongly unequal, suborbicular or broadly ovate-orbicular, the 2 outer 1.2 to 1.4 mm. wide, the inner 1.5 to 2.2 mm. wide, margin obscurely and minutely erose, reddish. Petals broadly obovate or suborbicular, 2 to 2.4 mm. long, margin very minutely erose. Disk usually pentagonous, rather thick, about 1.8 mm. wide, subcupular. Filaments inserted on angles of disk, about 1 mm. long; anthers broadly cordate, about 0.5 mm. long, short apiculate. Rudimentary ovary almost entirely submerged in disk, contracted above into a short style, incompletely 2-celled, with 4 collateral ovules on a short central placenta. Pistillate flowers and fruits unknown.

Type in the Herbarium of the Field Museum of Natural History (No. 599,103), *P. C. Standley and Juvenal Valerio 50602*, collected on Cerros de Zurquí, northeast of San Isidro, Province of Heredia, COSTA RICA, alt. 2000–2400 m., Mar. 3, 1926.

Additional specimens examined: COSTA RICA: Province of Heredia, Cerros de Zurquí, northeast of San Isidro, alt. 2000–2400 m., Mar. 3, 1926, *Standley and Valerio 50602*, staminate flowers, type collection (US); *Standley and Valerio 50480*, staminate flowers (F, US). Province of San José, Zurquí, alt. 2000–2500 m.; shrub in wet forest; Feb. 13, 1926, *Standley and Valerio 48169*, staminate flowers (US).

M. Standleyi is related to *M. Schiedeana* Loes. of Vera Cruz, but may be readily distinguished by its chartaceous leaves with main lateral veins 4 or 5 on each side, these strongly ascending from base at an acute angle, arcuately ascending from medial region. In *M. Schiedeana* the leaves are

subcoriaceous with main lateral veins 7 to 9 on each side, these patent, nearly horizontal.

Wimmeria acapulcensis sp. nov. (fig. 1).—Frutex. Folia 5–15 mm. longe petiolata, subcoriacea, remote et inconspicue serrulata, lanceolata vel ovata, 4.5–7 cm. longa, 2–3.8 cm. lata, apice obtusa vel rotundata, basi attenuata, acuminata, costa ad apicem utrinque debili, venis supra albidis, inconspicuis, subtus leviter impressis, obscuris. Cymae minute puberulae, longe pedunculatae. Pedicelli 5–6 mm. longi, ad basin puberuli. Calycis lobi inaequales, 1.4–2.5 mm. lati. Petala 5, minute pulverulento-puberula, suborbicularia, ca. 3 mm. longa secus medietatem, marginibus ca. 0.8 mm. ultra apicem productis. Filamenta ca. 2.3 mm. longa. Ovarium 3- raro 2-loculare, stylo crasso, ca. 0.8 mm. longo. Fructus depresso-orbiculares, 13–18 mm. longi, 18–22.5 mm. lati.

"A spreading shrub 24 dm. high" (Rose); branchlets pale, rather stout, compressed and strongly striate, puberulent around the nodes, glabrous otherwise. Leaves subcoriaceous, brittle, slightly paler beneath, borne mainly on short spur-like branches. Stipules minute. Petioles 5 to 15 mm. long, slender, shallowly canaliculate, puberulent above, the medial ridge conspicuous. Leaf blades lanceolate or ovate, 4.5 to 7 cm. long, 2 to 3.8 cm. wide, apex bluntly obtuse to rounded, base attenuate, acuminate, decurrent, costa prominent at base beneath, less conspicuous above, becoming faint near the apex, veins nearly plane above, whitened, impressed and almost obsolete beneath, margin remotely and inconspicuously serrulate with minute appressed nigrescent teeth. Cymes puberulent, long pedunculate, forked 1 to 3 times, the ultimate branches shortened, crowding the flowers. Bracts and bractlets minute, with toothed margins, the teeth red. Pedicels slender, puberulent only at base, 5 to 6 mm. long, jointed at base. Calyx 5-lobed, the lobes unequal, broadly rounded, 1.4 to 2.5 mm. wide, minutely apiculate, very minutely erose-ciliolate. Petals 5, minutely pulverulent-puberulent outside, 7- or 8-veined, suborbicular, 3 mm. long medially, with the overlapped margin prolonged laterally at apex as much as 0.8 mm., about 3.2 mm. wide, rufous-punctate, free margin very minutely ciliolate, overlapped margin erose. Stamens 5; filaments filiform-subulate, about 2.3 mm. long, inserted on lower edge of disk; anthers 1 mm. long. Disk thick, nearly flat, confluent with base of ovary, slightly rugose, minutely papillate. Ovary 3-winged, rarely 2-winged, 3-celled, rarely 2-celled, base submerged in disk. Style thick, terete, about 0.8 mm. long. Stigma subcapitate, trifid, rarely bifid. Fruits 3-winged, rarely 2-winged, usually broadest at the middle, depressed-orbicular, much wider than long, 13 to 18 mm. long, 18 to 22.5 mm. wide, crowned by the persistent stigma and style, deeply notched at apex and base, the wings membranous, with close veins; 1-seeded.

Type in the Herbarium of Arnold Arboretum, *Edward Palmer 124*, collected near Acapulco, Guerrero, Mexico, Nov. 1894.

Fig. 1. *Wimmeria acapulcensis* Lundell. Type collection (*Palmer 124*), in Missouri Botanical Garden Herbarium. $\times\frac{1}{4}$

Additional specimens examined: MEXICO: Guerrero, Acapulco and vicinity, Nov. 1894, *Palmer 124*, type collection (G, Mo, US).

Palmer 124 was described by Rose who made the untenable proposal to transfer the name *W. pallida* Radlk. to this species. (Contr. U. S. Nat. Herb. 5: 130. 1897.) *Hartweg 41* (fig. 2) is the type collection of *W. confusa* Hemsl., and *W. pallida* Radlk. (as to flowers). *W. confusa* has priority, hence *W. pallida* is clearly a synonym.

W. acapulcensis is very distinct from *W. confusa* (compare figs. 1 and 2), differing markedly in its much larger bluntly obtuse or rounded leaves and larger fruits. It is also related to *W. lanceolata* Rose and *W. persicifolia* Radlk. but may be readily distinguished as both of these have long attenuate-acuminate leaves.

Wimmeria Bartlettii sp. nov.—Arbor glabra, 27 m. alta, 60 cm. diam. Folia 7–12 mm. longe petiolata, coriacea, lanceolata, lanceolato-oblonga vel elliptica, 6–13.5 cm. longa, 1.8–5.5 cm. lata, utrinque acuminata, serrulata. Cymae 1.3–3.5 cm. longae, pedunculatae. Pedicelli 3–13 mm. longi. Calyx profunde quinquefidus. Petala 5, late ovata, ca. 3 mm. longa in medietatem, marginibus lateralibus productis, fimbriatis, fimbriis saepe 1.3 mm. longis. Stamina 5. Filamenta 2.2–3 mm. longa. Antherae 1–1.2 mm. longae. Ovarium 3- raro 4-loculare. Fructus late ovati, suborbiculares vel oblongi, 3.5–5.2 cm. longi, 3–4 cm. lati.

A tree reaching a height of 27 m. and a diam. of 60 cm. (Bartlett, Lundell), with smooth gray bark; entirely glabrous; branchlets green, rather stout, striate. Leaves large, petiolate, coriaceous, slightly discolorous. Stipules minute, subulate, less than 1 mm. long. Petioles 7 to 12 mm. long, subcanaliculate above with a fine medial ridge. Leaf blades lanceolate, lanceolate-oblong, or elliptic, 6 to 13.5 cm. long, 1.8 to 5.5 cm. wide, acuminate at both ends, costa raised above as a narrow fine ridge extending nearly to apex, prominent beneath, main lateral veins 6 to 9 on each side, arcuately ascending, prominulous to obscure on both surfaces, veinlets usually inconspicuous and obscure, rarely slightly impressed, margin serrulate, the teeth subulate-tipped with appressed nigrescent teeth. Cymes 1.3 to 3.5 cm. long, pedunculate, forked 2 to 4 times. Bracts and bractlets broadly triangular, acutish, 0.35 to 0.8 mm. long. Flowers green (Bartlett). Pedicels slender, 3 to 13 mm. long, jointed at base. Calyx rather thick, 5-lobed, the lobes imbricate, broadly ovate-triangular, rounded or bluntly obtuse. Corolla contorted, very rarely imbricate; petals 5, broadly ovate, about 3 mm. long medially, the overlapped margin prolonged laterally at apex, thin, conspicuously fringed, the fimbriae as much as 1.3 mm. long. Stamens 5; filaments filiform-subulate, 2.2 to 3 mm. long, inserted at edge of disk; anthers 1 to 1.2 mm. long. Disk large, rather flat, thick, rugose, shallowly 5-lobed, confluent with base of ovary, distinctly glandular-punctate. Ovary usually 3-angled, 3- rarely 4-celled, base submerged in disk. Style very short, usually triquetrous. Stigma trifid. Fruits crimson

Fig. 2. *Wimmeria confusa* Hemsl. Type collection (*Hartweg 41* from Zacatecas), in Kew Herbarium. $\times\frac{3}{4}$.

(Bartlett) or reddish-brown (Schipp), 3- rarely 4-winged, broadly ovate, broadly elliptic, or oblong in outline, 3.5 to 5.2 cm. long, 3 to 4 cm. wide at maturity, deeply cordate at base, shallowly emarginate to deeply notched at apex, crowned by the persistent stigma and style, the wings broad, membranous, with numerous fine close veins; 1- or 2-seeded, the seed erect, straight, linear, subterete, up to 1.8 cm. long, the testa finely verrucose, dark red; endosperm abundant; cotyledons flat, equal, linear-lanceolate, about 14 mm. long, apex obtuse; radicle up to 1.8 mm. long, subterete.

Type in the Herbarium of the University of Michigan, *H. H. Bartlett 12435* (flowers), *12773* (fruits), collected in sapodilla and mahogany forest at Uaxactun, Department of Petén, Guatemala, April 2nd and 27th, 1931.

Additional specimens examined: GUATEMALA: Department of Petén, Uaxactun, in sapodilla and mahogany forest, March 21, 1931, *Bartlett 12216*, sterile (A, M); April 2, 1931, *Bartlett 12435*, type collection of flowers (A, Mo, NY, US); April 6, 1931, *Bartlett 12481*, flowers and fruits (A, D, M, NY, US); April 8, 1931, *Bartlett 12536*, flowers (A, M); April 27, 1931, *Bartlett 12773*, type collection of fruits (NY). La Libertad, Monte Chicbul, in forest on slope of limestone hill, *C. L. Lundell 2640*, sterile (M). Department of Izabal, lower Rio Dulce, March 2, 1885, *Sereno Watson 43*, fruits (G, K). BRITISH HONDURAS: El Cayo District, Valentin, in advanced, valley forest on limestone, June 27, 1936, *Lundell 6278*, flower buds (M-2). Toledo District, Temash River, on river bank in shade, April 22, 1934, *W. A. Schipp 1296*, fruits (A, F, G, M, Mo, NY).

Vernacular names: "*Quiebra hacha blanco*" (*Bartlett 12216*); "*Chintoc*" (*Bartlett 12435*); "*Ixolte ixnuc*" (*Bartlett 12481*).

Economic value: The wood is utilized locally for xylophone keys (Bartlett).

W. Bartlettii may be readily separated from the closely related *W. concolor* Schl. & Cham. by its much larger fruits as well as the fringed overlapped margin of the petals, the petals of *W. concolor* being merely erose on the overlapped margin.

Zinowiewia australis sp. nov.—Arbor 20 m. alta. Folia 6–8 mm. longe petiolata, subchartacea, ovato-elliptica, lanceolata vel elliptica, 5–8 cm. longa, 2.3–3.7 cm. lata, apice acuminata, acumine acutiusculo, basi abrupte attenuata, acuta. Fructus late oblanceolati vel obovati, 2–2.4 cm. longi, 7.5–9.5 mm. lati, apice rotundati, apiculati, valide venosi. Semen 1; cotyledonibus lanceolatis, 6.8–7.5 mm. longis, 2–2.1 mm. latis, apice rotundatis; radicula 3 mm. longa.

A tree about 20 m. high; branchlets slender. Leaves subchartaceous, dark green. Petioles slender, deeply canaliculate, 6 to 8 mm. long. Leaf blades

ovate-elliptic, lanceolate, or elliptic, 5 to 8 cm. long, 2.3 to 3.7 cm. wide, apex acuminate, the acumen acutish, base abruptly narrowed, acute, decurrent, costa slightly elevated above at base, prominent beneath, reticulate-veined, the main lateral veins 4 to 6, margin revolute. Cymes subsessile, forked 4 or 5 times, the primary branches much shortened. Fruits broadly oblanceolate to obovate, 2 to 2.4 cm. long. 7.5 to 9.5 mm. wide, strongly veined, the veins nearly horizontal above the middle, veinlets well-developed from margin of wing, apex rounded, apiculate; 1-seeded, the seed 9 to 11 mm. long, 2.5 to 3 mm. in diam., subterete, nearly straight, the ends narrowed, rounded; cotyledons lanceolate, 6.8 to 7.5 mm. long, 2 to 2.1 mm. wide, rounded at apex; radicle linear, quadrangulate, 3 mm. long.

Type in the Herbarium of the Field Museum of Natural History (No. 894,843), *H. Pittier 13826*, collected in "Selvas nubladas, Agua y El Junquito," Venezuela, December 29, 1936, at alt. of 1800 m.

Vernacular name: "*Canalete*" (Pittier).

Z. australis is noteworthy for its dark green thin leaves, large obovate strongly veined samaras 20 to 24 mm. long and 7.5 to 9.5 mm. wide, and cotyledons 2 to 2.1 mm. wide.

Zinowiewia concinna sp. nov.—Arbor. Folia 4–8 mm. longe petiolata, subcoriacea, ovata, elliptico-oblonga vel lanceolata, 5.5–11 cm. longa, 2.5–4.5 cm. lata, apice abrupte acuminata, basi acuta. Cymae 1.3–2.5 cm. longae. Calyx profunde quinquefidus, lobis ca. 0.5 mm. longis, rotundatis. Petala 5, late ovata vel ovato-oblonga, 1.5–1.7 mm. longa, 1–1.2 mm. lata. Filamenta ca. 0.6 mm. longa. Antherae ca. 0.4 mm. longae. Ovarium in discum immersum. Fructus oblanceolati, 2–2.2 cm. longi, 6.5–7 mm. lati, acutiusculi, apiculati, venis debilibus. Semen 1; cotyledonibus lineari-lanceolatis, ca. 5.5 mm. longis, obtusis; radicula ca. 2.7 mm. longa.

A small tree (Pringle) or large tree (Hinton). Leaves subcoriaceous or subchartaceous. Petioles 4 to 8 mm. long, canaliculate. Leaf blades ovate, elliptic-oblong, or lanceolate, 5.5 to 11 cm. long, 2.5 to 4.5 cm. wide, apex acuminate, the acumen obtusish or acute, base acute, decurrent, costa nearly plane above or slightly impressed, prominent beneath, openly reticulate-veined, the main lateral veins 6 to 8 on each side. Cymes subsessile or short pedunculate, 1.3 to 2.8 cm. long, forked 4 to 6 times, the primary branches usually much shortened, crowded. Pedicels 2 to 3.5 mm. long, slender, jointed at or near the middle. Calyx 5-lobed, the lobes about 0.5 mm. long, the margins bearing slender red deciduous teeth. Petals 5, broadly ovate or ovate-oblong, 1.3 to 1.7 mm. long, 1 to 1.2 mm. wide, apex rounded. Filaments about 0.6 mm. long. Anthers about 0.4 mm. long. Disk pentagonal. Ovary submerged in disk; ovules small, about 0.25 mm. long. Fruits subfalcate, oblong-elliptic, 2 to 2.2 cm. long, 6.5 to 8 mm. wide, acutish or obtusish, apiculate, venation faint; seed linear-oblong, 8 to 10 mm. long; cotyledons linear-lanceolate, about 5.5 mm. long, obtuse; radicle about 2.7 mm. long, slender.

Type in the Herbarium of the University of Michigan, *C. G. Pringle 8438*, collected on Sierra de Tepoxtlan, near Cuernavaca, Morelos, Mexico, September 11, 1900, at alt. of 2450 m.

Additional specimens examined: MEXICO: Morelos, Sierra de Tepoxtlan, Feb. 8, 1899, *Pringle 8024* (A, C, F, G, Mo, P, US-2); Sept. 11, 1900, *Pringle 8438*, type collection (A, C, F, G, Mo, NY, P, US-2); Nov. 20, 1902, *Pringle 9706* (F, G, NY, Mo, US-2). Michoacan, Sta. Maria, Oct. 1909, *Arsene* (F). State of Mexico, District of Temascaltepec, Mina de Agua, alt. 1990 m., Oct. 31, 1932, *G. B. Hinton 2332* (K, US); Feb. 4, 1933, *Hinton 3253* (K).

Vernacular name: "*Gloria*" (Hinton).

Economic value: "Used in necessity for fodder" (Hinton).

The faintly-veined acutish wing of its oblong-elliptic samaras, the long pedicels, and the obtusish or acute acumen of the leaves distinguish *Z. concinna* from *Z. integerrima* (Turcz.) Turcz. to which it is very closely related. *Z. integerrima* has broadly oblanceolate or obovate rounded more strongly veined samaras, much larger cymes, shorter pedicels, and bluntly obtuse subacuminate leaves.

Zinowiewia costaricensis sp. nov.—Arbor. Folia 4–9 mm. longe petiolata, chartacea, parva, lanceolata, 3.5–8.5 cm. longa, 1.3–2.8 cm. lata, utrinque acuminata. Cymae ca. 1.5 cm. longae. Calyx profunde quinquefidus, lobis ca. 0.5 mm. longis, rotundatis. Petala 5, late ovata vel suborbicularia, 1.1–1.3 mm. longa, 1–1.1 mm. lata, apice rotundata, inconspicue erosa. Fructus oblanceolato-oblongi, 1.5–2.1 cm. longi, 5–6.5 mm. lati, apice emarginati. Semen 1 vel 2; cotyledonibus lineari-lanceolatis, 5.2 mm. longis, ca. 1.2 mm. latis, apice rotundatis; radicula 2.3 mm. longa.

A tree; branchlets slender. Leaves chartaceous, discolorous. Petioles slender, 4 to 9 mm. long, shallowly canaliculate. Leaf blades lanceolate, 3.5 to 8.5 cm. long, 1.3 to 2.8 cm. wide, apex and base acuminate, decurrent, much paler beneath, costa slightly raised above, prominent beneath, the main lateral veins 4 to 6 on each side. Cymes small, usually about 1.5 cm. long, forked 3 or 4 times. Calyx 5-lobed, the lobes rounded, about 0.5 mm. long. Petals 5, broadly ovate to suborbicular, 1.1 to 1.3 mm. long, 1 to 1.1 mm. wide, rounded at apex, inconspicuously erose. Margin of disk raised. Fruits oblanceolate, 1.5 to 2.1 cm. long, 5 to 6.5 mm. wide, subfalcate (1-seeded) or straight (2-seeded), venation of wing strongly ascending, faint, scarcely discernible near the margin, apex emarginate; 1-celled and 1-seeded, or 2-celled and 2-seeded, the seed erect, linear-oblong in outline, terete, 6 to 8 mm. long, apex rounded; cotyledons linear-lanceolate, rounded at apex, 5.2 mm. long, about 1.2 mm. wide; radicle 2.3 mm. long.

Type in the United States National Herbarium (No. 471,825), *Tonduz*

7861, collected on Cuesta de Terrazu, Costa Rica, at alt. of 1900 m. in April 1893.

Additional specimens examined: COSTA RICA, Cuesta de Terrazu, April 1893, *Tonduz 7861*, type collection (US-No. 577,182). Monte Candelaria, February 1847, *Oersted 116K* (F-fragment, US). PANAMA, vicinity of El Boquete, Chiriqui, alt. 1000 to 1300 m., March 2–8, 1911, *W. R. Maxon 5109* (F-2).

Z. costaricensis is noteworthy for having emarginate fruits 1- or 2-seeded, all the other species in the genus being strictly 1-seeded so far as known. The relatively small, discolorous, lanceolate leaves, acuminate at apex and base, distinguish the species further. The Oersted and Tonduz collections, excepting No. 577,182 (US), are homogeneous. In the Tonduz specimen, No. 577,182, apparently taken from a different tree than the type specimen, the fruits appear abnormal, being smaller than usual and obtusish. The leaves, however, are typical.

The Panama specimens, referred tentatively to *Z. costaricensis*, have leaves ovate or ovate-lanceolate, cymes as much as 3 cm. long, and petals slightly larger (about 0.2 mm. longer and proportionately wider). Young fruits are typically emarginate, but slightly broader; all of those available are 1-seeded.

Zinowiewia Matudai sp. nov.—Arbor 7–9 m. alta, 15 cm. diam. Folia 7–11 mm. longe petiolata, chartacea vel subcoriacea, anguste oblonga, oblongo-elliptica, vel oblanceolata, 5–9 cm. longa, 2–3.5 cm. lata, apice acuminata, acumine obtusiusculo vel acuto, basi subacuminata. Cymae 1.4–2.4 cm. longae. Flores purpurei. Calyx profunde quinquefidus, lobis late ovatis, ca. 0.5 mm. longis, obtusiusculis vel rotundatis. Petala 5, ovata, 1.6–2 mm. longa, 1–1.2 mm. lata, obtusiuscula vel rotundata. Filamenta ca. 0.7 mm. longa. Antherae ca. 0.25 mm. longae. Ovarium in discum subimmersum. Fructus oblongi, 12–15 mm. longi, 4–5 mm. lati, apice obtusi, apiculati, venis debilibus. Semen 1, cotyledonibus lineari-lanceolatis, ca. 3 mm. longis, obtusis; radicula 1.2–1.4 mm. longa.

A tree 7 to 9 m. high, 15 cm. in diam.; branchlets slender, drying reddish-black, striate, slightly compressed at nodes. Leaves chartaceous at first, subcoriaceous with age, drying yellow-green, somewhat paler beneath. Petioles slender, 7 to 11 mm. long, canaliculate, reddish. Leaf blades narrowly oblong, oblong-elliptic, or oblanceolate, 5 to 9 cm. long, 2 to 3.5 cm. wide, apex acuminate, the acumen obtusish or acute, base subacuminate, distinctly callosed and revolute on each side, costa prominent beneath, slightly impressed above, openly reticulate-veined beneath, main lateral veins 6 to 8 on each side, prominulous beneath, inconspicuous above, arcuately ascending, anastamosing into a submarginal vein. Cymes 1.4 to 2.4 cm. long, pedunculate, forked 3 to 5 times, the branches short, crowding the flowers.

Flowers purplish (Matuda). Pedicels very short, usually less than 0.5 mm. long, jointed at or near the middle. Calyx 5-lobed, the lobes broadly ovate, about 0.5 mm. long, obtusish or rounded. Petals 5, ovate, 1.6 to 2 mm. long, 1 to 1.2 mm. wide, obtusish or rounded. Filaments subulate, about 0.7 mm. long. Anthers about 0.25 mm. long. Disk thick, pentagonal. Ovary almost entirely submerged in disk. Style slender, equaling filaments in length. Samaras oblong-elliptic, 12 to 15 mm. long, 4 to 5 mm. wide, subfalcate, the wing decurrent to base on side opposite seed, lateral veins above middle of wing nearly horizontal, faint, veinlets undeveloped from margins, apex obtuse or bluntly obtuse, apiculate; 1-celled, 1-seeded, the seed erect, lanceolate-oblong in outline, 4.5 to 5 mm. long, nearly terete, reddish; cotyledons linear-lanceolate, about 3 mm. long, obtuse; radicle 1.2 to 1.4 mm. long.

Type in the Herbarium of the University of Michigan, *Eizi Matuda 1872*, flowers and fruits, collected at Buena Vista, Escuintla, Chiapas, Mexico, January 1938.

Additional specimens examined: MEXICO: Chiapas, Mt. Ovando near Escuintla, Dec. 17, 1936, *Matuda 424*, flowers and fruits.

The callosed revolute base of the leaf blades, evident in the youngest unfolded leaves, is a peculiarity of this species. The yellow-green hue of the leaves, the purplish subsessile flowers, and the small fruits and seeds distinguish it further. Its closest relative is *Z. rubra* Lundell of Guatemala.

Zinowiewia pallida sp. nov. (fig. 3).—Arbor glabra, 10 m. alta, 10 cm. diam. Folia 3–5 mm. longe petiolata, pallida, subcoriacea, oblanceolata, raro oblanceolato-elliptica, 4–9.5 cm. longa, 1.4–3.3 cm. lata, apice obtusa, raro rotundata, minute apiculata, basi acuminata. Flores parvi, pallide virides. Calyx profunde quinquefidus, lobis ca. 0.4 mm. longis, rotundatis. Petala 5, late ovata, 1.2–1.3 mm. longa, ca. 1 mm. lata. Stamina 5; filamentis ca. 0.5 mm. longis; antheris late cordatis, ca. 0.3 mm. longis. Ovarium in discum immersum. Fructus immaturus samaroideus.

A tree 10 m. high and 10 cm. in diameter, with short trunk; branchlets slender, red at first, whitened in age. Leaves pallid, subcoriaceous. Petioles reddish, 3 to 5 mm. long, slightly canaliculate. Leaf blades oblanceolate, rarely oblanceolate-elliptic, 4 to 9.5 cm. long, 1.4 to 3.3 cm. wide, apex obtuse or rarely rounded, minutely apiculate, base acuminate, slightly decurrent, discolorous, the young leaves whitish beneath, costa elevated above on lower half of blade, pinkish and very prominent beneath the entire length, main lateral veins 5 to 8 on each side, inconspicuous above, prominulous beneath, anastamosing near the margin. Cymes 2 to 2.8 cm. long, pedunculate, forked 4 or 5 times, open. Flowers small, pale green. Pedicel of terminal flower in cymules 1.2 mm. long, jointed at base; pedicels of lateral flowers in ultimate cymules about 2 mm. long, jointed at middle. Calyx 5-lobed, the lobes about 0.4 mm. long, rounded. Petals 5, broadly ovate, 1.2 to 1.3 mm. long, about 1

Fig. 3. *Zinowiewia pallida* Lundell. Type specimen (*Lundell 6794*), in Herbarium of the University of Michigan. ×¾.

mm. wide. Filaments about 0.5 mm. long. Anthers about 0.3 mm. long. Disk thick, pentagonal, margin nearly plane. Ovary submerged in disk. Young immature fruits samaroid, typical of genus.

Type in the Herbarium of the University of Michigan, *C. L. Lundell 6794*, collected in open granite bed of Rio On, Mountain Pine Ridge, El Cayo District, British Honduras, Aug. 5, 1936.

In its obtuse rather than subacuminate or acuminate leaves, *Z. pallida* differs from all other species in the genus. It is evidently related to *Z. integerrima* (Turcz.) Turcz.

Zinowiewia rubra sp. nov.—Arbor 30 m. alta, 75–90 cm. diam. Folia 3.5–11 mm. longe petiolata, subchartacea vel subcoriacea, lanceolata vel lanceolato-elliptica, 4–11 cm. longa, 1.5–3.5 cm. lata, acuminata vel subacuminata, acumine acuto vel obtusiusculo, basi acuminata vel acuta. Cymae 2 cm. longae vel breviores. Flores rubri. Calyx profunde quinquefidus, lobis late triangulari-ovatis, ca. 0.5 mm. longis, obtusis. Petala 5, ovata, 2–2.2 mm. longa, ca. 1.5 mm. lata, apice rotundata. Filamenta ca. 0.75 mm. longa. Antherae minutae, ca. 0.2 mm. longae. Ovarium in discum immersum. Semen 1.

A large tree; branchlets dark red, rather stout, internodes short or elongated. Leaves subchartaceous or subcoriaceous. Petioles 3.5 to 11 mm. long, reddish. Leaf blades lanceolate or lanceolate-elliptic, 4 to 11 cm. long, 1.5 to 3.5 cm. wide, apex usually acuminate, sometimes subacuminate, the acumen acute or obtusish, base acuminate or acute, decurrent, costa narrow above, pinkish and prominent beneath, openly reticulate-veined, the main lateral veins 5 to 8 on each side. Cymes 2 cm. long or less, short pedunculate or subsessile, the peduncles and branches stout, forked 2 to 4 times. Flowers crowded, maroon or tinged maroon. Pedicel of terminal flower in cymules about 1.2 mm. long, jointed at or above the middle; pedicels of all lateral flowers jointed above the middle. Calyx 5-lobed, the lobes broadly triangular-ovate, about 0.5 mm. long, obtuse. Petals 5, ovate, 2 to 2.2 mm. long, about 1.5 mm. wide, apex rounded. Filaments subulate, about 0.75 mm. long. Anthers minute, about 0.2 mm. long. Disk green, pentagonal. Ovary submerged in disk. Immature fruits oblong-elliptic, dull red (*Skutch 1680*), 1-seeded, obtusish.

Type in the Herbarium of the University of Michigan, *A. F. Skutch 639*, a tree 75 cm. in diam., flowers maroon with a green disk, in clearing above Tecpam, Department of Chimaltenango, Guatemala, alt. 2800 m., Oct. 14, 1933.

Additional specimens examined: GUATEMALA: Department of Chimaltenango, Tecpam, *Skutch 639*, type collection (D, NY, US). Department of Quiché, Nebaj, a tree to 30 m. high and 90 cm. in diam., flowers green tinged with maroon, fruits dull red, in remnant of cloud

forest, alt. 2550 m., Nov. 16, 1934, *Skutch 1680*, flowers and young fruits (F).

Z. rubra, the largest tree in the genus, may be easily recognized by its comparatively large maroon or maroon tinged petals as much as 2.2 mm. long and 1.5 mm. wide. It is closely related to *Z. Matudai*, but differs in its longer pedicels, larger flowers, green rather than yellow-green leaves, and the absence of the callosed revolute base of the leaf blades.

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The emergence of smut-inoculated oat seedlings through sand and loam soil[1]

PAUL F. BRANDWEIN
(WITH ONE FIGURE)

In experiments on the nature of smut infection in various oat varieties, the writer has observed the emergence through sand of seedlings inoculated with the loose smut, *Ustilago avenae* (Pers.) Jens., and the covered smut, *U. levis* (Kell. and Sw.) Magn. In experiments involving the use of approximately 10,000 seeds, half of which were uninoculated controls, there was 98.7 per cent emergence of plants from uninoculated seeds as compared with 97.2 per cent emergence of plants from seed inoculated with different races of smuts maintained at the Brooklyn Botanic Garden. However, Bayles and Coffman (1) have shown that dehulling reduced the emergence through soil of plants grown from uninoculated seed by 5.8 per cent and of inoculated seed by 10.6 per cent. Stevens (2) in field experiments reported that the smut-resistant Markton oat is injured by inoculation that results in the killing of many seeds and thus reduces the stand. After the seedlings emerge, however, there appeared to be no detrimental results. These observations pointed to the desirability of conducting experiments to discover some reason for these differences in emergence of seedlings through soil and sand.

The technique generally employed in this laboratory was used with the exception that seeds were planted in soil as well as in sand for purposes of comparison. The soil used was a good loam soil, screened through a 40 mesh sieve. The sand was similarly sieved through the same mesh.

In these experiments 110 cc. of soil or sand was placed in a waxed paper cup. The cup was then tapped several times on the table and ten seeds were placed at approximately equidistant points on this sand or soil base, and covered with an equivalent quantity.

Both sand and soil had a moisture content of 20 per cent of their water holding capacity and the cups were maintained at a constant temperature of 20°C. The ten seeds had been placed in coin envelopes and inoculated with about 10 milligrams of smut spores, the excess being spread as evenly as possible when planted. The dehulled seeds of the varieties Monarch and Markton were inoculated with the Missouri race of *Ustilago levis*, to which Monarch is very susceptible and to which Markton is highly resistant.

Four different plantings were made: soil only, sand only, soil base with sand cover and sand base with soil cover. All four sets were planted

[1] Brooklyn Botanic Garden Contribution No. 86.

simultaneously, 100 seeds being used in each set. The emergence of seedlings was recorded as follows:

	Per cent emergence	
	Inoculated	*Uninoculated*
Markton—Soil only	98	99
Sand only	100	100
Soil base, sand cover	99	98
Soil cover, sand base	100	100
Monarch—Soil only	98	98
Sand only	99	98
Soil base, sand cover	100	99
Soil cover, sand base	98	99

From the results, it seems clear that under these conditions, the emergence of the seedlings might be considered unaffected by soil, the slight difference in Markton being insignificant. However, these conditions do not simulate those present in the field. Plantings, therefore, were made in the field as described in a previous paper (3) with the exception that the seeds were immediately planted three inches beneath the surface of the soil. The rows of dehulled inoculated seed alternated with those which were inoculated. Two hundred seeds were used in each planting.

	Per cent emergence	
	Inoculated	*Uninoculated*
Markton—Plantings of April 10	90	96
Plantings of April 25	86	94
Plantings of May 22	88	94
Monarch—Plantings of April 10	80	88
Plantings of April 25	84	96
Plantings of May 22	80	92

From the field experiments there seems to be a definite reduction of the emergence through soil of plants from inoculated seed. The emergence of seedlings of Markton was reduced by 6.7 per cent and of Monarch by 10.7 per cent. This apparently confirmed the results of Bayles & Coffman (1) and of Stevens (2).

While no attempt had been made to tamp the soil other than to pat it firmly in place, careful examination showed that within a day or so, in the field, the soil had become packed to a varying extent in different portions of the experimental plot. This pointed to tamping as one of the factors which must be considered in evaluating the percentages of emergence of seedlings. Preliminary experiments were therefore begun with the added procedure that the soil or sand was tamped to simulate the observed condition of the soil in the field.

In sand, with light tamping (i.e., merely tapping the sand in place with

a wooden tamper) under the conditions of constant moisture and temperature previously described, there was 100 per cent emergence of Monarch and Markton seedlings from uninoculated seed as well as from seed inoculated with *U. levis*. Where a loam soil was allowed to settle on the seeds by tapping the waxed paper cups in which the germination was carried on, there was 98 per cent emergence of seedlings from inoculated seeds of Markton and 99 per cent emergence of the uninoculated controls. The

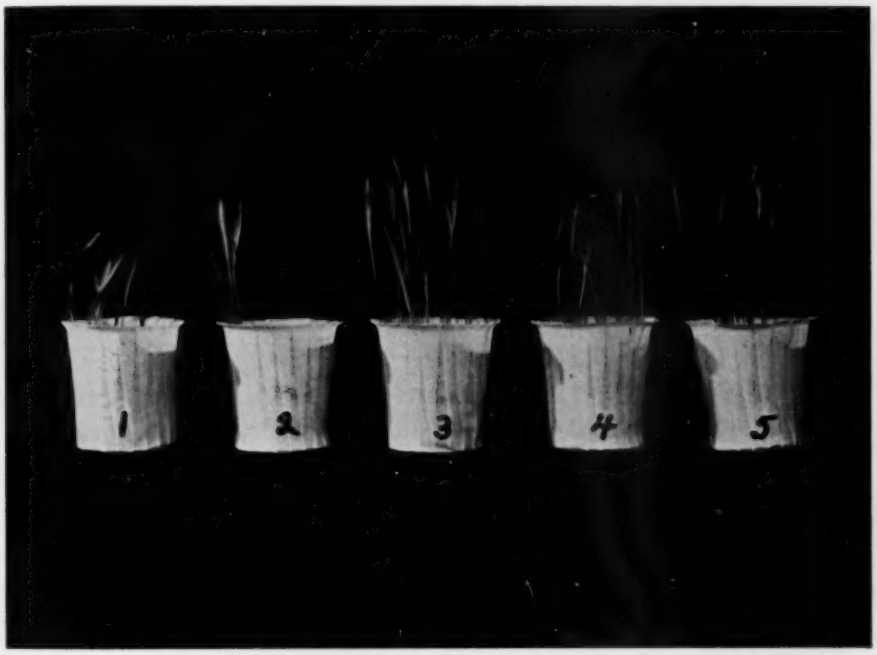

Fig. 1. Emergence of seedlings of Markton in heavily tamped soil and sand. (1, 2) inoculated with *Ustilago levis*, in heavily tamped loam soil; (3) the same, in heavily tamped sand; (4) uninoculated, in heavily tamped loam soil; (5) uninoculated, in heavily tamped sand.

Photograph taken 14 days after planting.

slightly lower emergence in soil as compared with sand may be accounted for by the various seedling-rot fungi which were present in the soil. However, when the loam soil was tamped as heavily as possible in the cups by pressing on the wooden tamper, so that the folds of the cup were slightly separated by the force used, there was a remarkable difference in the behavior of inoculated and uninoculated seeds. In such cases of heavy tamping, the emergence from inoculated seeds of the susceptible Monarch was reduced to an average of 55.5 per cent as compared with 82.5 per

cent emergence from the uninoculated controls. The emergence of plants of the resistant Markton variety was reduced to 75.3 per cent as compared with 90 per cent emergence from the uninoculated seed.

In sand, however, such heavy tamping had little effect in reducing emergence (fig. 1). In Markton, the emergence of inoculated seedlings through such heavily tamped sand (as described above for soil) was 98 per cent as compared with 98.5 per cent for the uninoculated. In Monarch, the emergence of the inoculated seedlings was 96 per cent as compared with 97 per cent for the uninoculated. In heavily tamped sand, the inoculated seedlings were in some cases slightly smaller on emergence as compared with the uninoculated; but after emergence grew to the same height as in the uninoculated (fig. 1). In soil, there was a marked difference in date of emergence; inoculated plants generally emerged one-half to a day later than the uninoculated controls.

In no case was the average emergence number of the inoculated seedlings higher than the uninoculated ones of any single cup in a given series of plantings. While this made these results significant, it was decided to attempt to control the tamping. Plantings were therefore made in vials 30 mm. × 100 mm. with one seed to the vial. All vials were carefully measured to insure equality of height, depth and width. Thirty grams of sand, previously prepared by screening through the 40 mesh sieve and by moistening to 20 per cent of the water holding capacity, was used as a base and an equivalent amount of sand used as a cover. Another vial which slid easily into the planting vial was weighted with enough mercury to make its total weight 300 gms. As soon as 30 grams of the moistened sand had been placed in the larger vial, the latter was gently tapped to permit the sand to settle. Then the weighted vial was dropped from a carefully measured height (within the larger vial) on the sand. This height was approximately 25 mm. from the top of the sand. Depending on the severity of the tamping desired, the vial could be dropped as many times as necessary. After the sand base was tamped, the inoculated seed was placed centrally and about 2 milligrams of smut spores were added in excess. At this time the 30 grams of sand was added as the cover. This was then tamped as before. The vials were stoppered with a plug of non-absorbent cotton which was placed as near to the surface of the sand as possible. All the vials were placed in an incubator at 20°, the air being maintained approximately at saturation from two containers of water.

Since previous experiments had shown that sand could not be tamped as tightly as soil, it was decided to use a very heavy tamping in order to obtain measurable results. After several trials, it was decided to drop the 300 gram vial 20 times and to permit the growth of seedlings for 10 days

in this tightly packed sand. They were then removed for measurement and subjected to various other examinations dealing with the extent of smut infection. A control consisted in tamping the sand twice with the mercury weighted vial. The control seedlings were measured after three days, just before emergence.

The results obtained are summarized in table 1. It seems clear that there is a difference between the inoculated and non-inoculated plants under heavy tamping. Under light tamping in sand there is no difference

TABLE 1

Influence of tamping on the emergence of seedlings of Monarch and Markton oats inoculated with Ustilago levis, and non-inoculated controls.

VARIETY	PER CENT GERMINATION	AVERAGE HEIGHT IN MM.
Series A—tamped 20 times		
MONARCH		
Inoculated	75	16.3
Non-inoculated	95	25.0
MARKTON		
Inoculated	85	20.1
Non-inoculated	100	25.3
Series B—tamped twice		
MONARCH		
Inoculated	100	10.3
Non-inoculated	100	9.6
MARKTON		
Inoculated	100	11.8
Non-inoculated	100	12.8

In each experiment 40 seeds were planted.

The seedlings in Series A were measured when 10 days old, and those in Series B when 3 days old, in both series before emergence.

between the two. The latter fact bears out countless observations carried out in the Laboratory of Plant Pathology of the Brookyn Botanic Garden.

It is suggested that the marked smaller size of the inoculated seedlings of both the susceptible variety Monarch and the resistant variety Markton is in some measure due to the coleoptile invasion which has been found (3, 4, 5) to be present in resistant as well as susceptible varieties. Undoubtedly, in Monarch, and in Markton to a much lesser extent, the further mycelial penetration of other plant tissues plays some part in retarding the emergence of the plant under pressure. In Monarch, the mycelial invasion of the other plant tissues by *U. levis* is rapid. In Markton, too, Smith and Bressman (6) have reported several cases of smut sporulation when that variety was inoculated with various races of the covered

smut. In addition, Western (5) has shown some infection of the coleoptile and mesocotyl of Markton when inoculated with the covered smut; he did not note any infection of the growing point. The present writer (3) has noted at least one infection of the growing point of Markton by *U. levis*, and since then has had occasion to note two other cases of infection as evidenced by the sporulation of the smut. However, it appears (3, 4, 5) that for the great majority of resistant plants, the mycelium does not go further than the coleoptile. From observations made by Western and by the writer, it seems further evident that the extent of infection of the coleoptile of susceptible plants is much greater than that of resistant plants. Indeed, in the latter the infection sometimes is found to consist of a few attenuated and disorganized hyphae. It seems clear, however, that in resistant plants, the extent of the invasion by the mycelium may vary considerably.

In emergence, it appears to be the coleoptile which shields the tissues as the plant pushes through the soil or sand. It may be that the coleoptile is weakened by the mycelial invasion so that it cannot penetrate as effectively as does the uninoculated plant through tamped loam soil which furnishes the resistance that loosely tamped or loosely adhering particles of soil or sand do not present. This tamping effect may help to furnish a partial explanation of the results of Bayles & Coffman (1) and Stevens (2). In any case, my results point to the advisability of taking this tamping effect into consideration where experiments designed to test the susceptibility or resistance of an oat variety are conducted. In this Laboratory, preliminary plantings are made in loosely tamped sand in paraffin cups under constant moisture and temperature. After emergence the seedlings are transplanted to the field. In this manner, any adverse effects of tamping, damping-off fungi, shifting temperature, undependable conditions of moisture, are obviated. Furthermore, maximum infections are obtainable when this technique is used.

Many thanks are due to Dr. G. M. Reed for the material and the advice he has so unfailingly and generously given.

SUMMARY

Under severe tamping, the emergence of smut-inoculated seedlings of both susceptible and resistant oat varieties is reduced as compared with their uninoculated controls.

It is suggested that the coleoptile infection found by Kolk, Western and the present writer, to be present in inoculated resistant and susceptible oat varieties may be responsible for the failure of these plants to penetrate such tightly packed soil.

Examination of seedlings under heavy pressure shows a smaller size and lower germination of the inoculated plants as compared with their non-inoculated controls. Both Monarch, a susceptible variety, and Markton, a resistant form, showed similar reactions.

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Salt spray: An important factor in coastal ecology*

B. W. Wells and I. V. Shunk
(with three figures)

INTRODUCTION

Everyone who has visited sea coasts has noted the marked modification of form of woody plants close to the ocean; these are greatly repressed on the seaward side having a characteristic sloping form which has been universally called "wind form." The axes of the repressed shrub masses and of the one-sided trees are always in the direction of the strongest winds from the sea, which along most of the eastern U. S. coast are northeast (figs. 1 and 2).

The term "wind form" has not only had the descriptive connotation but the causal one as well. In Plant Sociology of Braun-Blanquet and Fuller (1932) is a statement and an illustration pointing to coastal winds as the cause of "wind form." Weaver and Clements in their Plant Ecology (1938) state, "On wind swept coasts and on high mountains excessive water loss results in a stunted and gnarled growth. This is, however, partly due to the mechanical effect of the wind." These books reflect the apparently obvious conception held by all observers to date, that wind is the factor involved.

The only report we have been able to find indicating injury by salt spray is that of Boodle,[1] who reaches the conclusion, "that the scorching of foliage by sea winds is chiefly due to the drying action of the wind but the salt may perhaps occasionally contribute toward the production of an injurious effect."

It is the purpose of this paper on the basis of observations made during the spring of 1937, to show that the "wind form" is not due to wind *per se* but to the salt spray carried by the wind, killing the growing shoots. This study brings to the front a factor almost unrecognized, yet of the greatest importance in coastal plant ecology.

THE EVIDENCE

On the North Carolina coast, with the exception of the low sea-elder shrub (*Iva imbricata*), no woody plants occur on the dunes next to the strand. Here the sea oats (*Uniola paniculata*) is strongly dominant accom-

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[1] Boodle, L. A. The scorching of foliage by sea winds. Jour. Ministry Agri. Great Britain **27**: 479–486. 1920.

panied by a few other herbs highly distinctive of this most exposed sea front zone. The woody plants occur on flats or low sandhills behind the sea front dunes.

Fig. 1. Spray forms (formerly called "wind forms") *Myrica cerifera* and *Ilex vomitoria* near Fort Fisher, 20 miles south of Wilmington, N. C. Spray repressed *Pinus Taeda* on left of road.

Fig. 2. Extreme spray form of *Quercus virginiana* near Nags Head, N. C., 55 miles north of Cape Hatteras.

Working on the seaward side of the Cape Fear peninsula below Wilmington, North Carolina, on April 16 we tagged a number of the new shoots of various "wind form" shrubs and trees found in this arboreal zone (fig. 1).

On April 30 we were surprised to find severe injury to the new shoots which occurred uniformly on the southeastern sides of the shrub masses. This definitely indicated some cause associated with a high southeast wind. The injury consisted of the killing of the upper younger tissues of the stems, the small immature leaves and the margins of the half developed leaves lower down, the necrotic areas of the latter appearing in a definite marginal pattern, extending proximally from the tip. It was noted that the most injured shoots were those most exposed. Those which were even slightly protected in shallow depressions in the compact shrub face, showed little or no injury. Upon checking the wind records at the Wilmington Weather Bureau Office (18 miles distant) we found a southeast wind of a relatively high intensity recorded for a period of 19 hours extending from the evening of April 24th to the afternoon of the 25th. This wind at the city station, 12 miles from the ocean, reached a maximum velocity of 28 miles per hour, the average, however, being 15.4 miles per hour. The seaside intensities would probably be much higher than these. No other wind approaching this one in duration or intensity occurred during the two-week interval. The sky during the high wind period was cloudy, and the soil water had been high in consequence of the frequent rains of the spring season. These two conditions eliminated the drying effect of the wind as a killing agent, forcing the conclusion that the injury must be ascribed to the salt spray carried in the wind.

Fortunately near the site of our original observations, nature arranged a perfect demonstration of this salt spray effect. Just south of the old Fort Fisher, relic of Civil War days, the peninsula suddenly narrows to little more than the width of the ocean strand and dune, due to the presence there of an estuary of the Cape Fear River. Stretched across the peninsula in front of this bay and facing directly to the southeast was a zone of the familiar coast shrubs dominated by the wax myrtle (*Myrica cerifera*) (fig. 3). A close examination of this shrub zone gave perfect confirmatory evidence that the further away from the sea a plant was located, the less noticeable was the injury. The first shrubs on which no injury was detectable were 280 yeards (.16 miles) from the sea, as measured on a direct line east from the ocean, and about $\frac{1}{2}$ mile from a point where a southeast wind could pick up the spray from the surf. Many of these uninjured shrubs were well isolated on the salt meadow fully exposed to east and southeast winds yet they showed not the slightest tendency to

a slope form in relation to the sea winds. Thus the southeast-facing shrub zone gave conclusive evidence of the role of the spray factor.

One observation still puzzled us. It was repeatedly noted on the repressed sea-front shrubs that, where the young and tender shoots were slightly depressed in the compact surface of the fastigiate twig mass, little or no injury occurred. So shoots of approximately equal surface area were taken from exposed and slightly depressed positions and carefully washed with equal amounts of distilled water. A few drops of silver nitrate solution were added to each of the washings. That from the exposed shoot gave a strong chloride precipitate, while that from the depressed shoot gave barely a trace. Why shoots so slightly depressed should escape from the spray, was puzzling until it was realized that a strong wind playing over a porous surface would set up a suction effect comparable to that familiar in atomizers, an effect which would result in a slight elevation of the spray-laden wind above the short spring growth slightly depressed in the shrub mass. A similar effect would keep the spray from falling behind the shrub mass, permitting the leeward lateral shoots to grow unimpeded. This phenomenon means that during the period of strong winds from the sea, there is set up a ground air current toward the sea. This air moves up through the interlacing branches and not only keeps the spray from settling into the shrubs but actually elevates the spray-laden wind slightly above their sloping surfaces. This effect is naturally most pronounced nearest the sea where the wind velocity is the highest, and where the spray is most concentrated.

At the same period in which all of the foregoing observations were made, we were able to produce exactly the same type of injury by spraying healthy juvenile shoots of wax myrtle, yaupon and live oak once or twice with sea water, and with distilled water containing a 3 per cent concentration of sodium chloride. The injury patterns resulting in both cases were identical with that from sea spray.

In contrast to these observations attention should be called to the fact that, where the wind sweeps across the sound estuaries of fresh water with little less velocity than it does over the ocean, no noticeable modification of the shore woody plants is discernible. Careful examination of those on the west shore of the Chowan River, 2 miles in width, showed not the slightest deviation from a uniformly symmetrical form among all the woody plants.

From the foregoing evidence, it is clear that a complete revaluation of the wind factor in coastal plant ecology must be made. Certainly on the coast of the Cape Fear peninsula, we can state categorically that the so-called "wind formed" shrubs are not wind formed at all but owe their

marked modification wholly to the killing action of the salt on the tender shoots during their growing period. These coastal malformed shrubs should therefore be called "spray forms."

NATURE OF THE INJURY

It may be assumed that, during the day-time exposure to spray, the concentration of the chlorides deposited on the plants is always higher than that of the sea water, owing to the rapid evaporation of the water by the high wind occurring at that time.

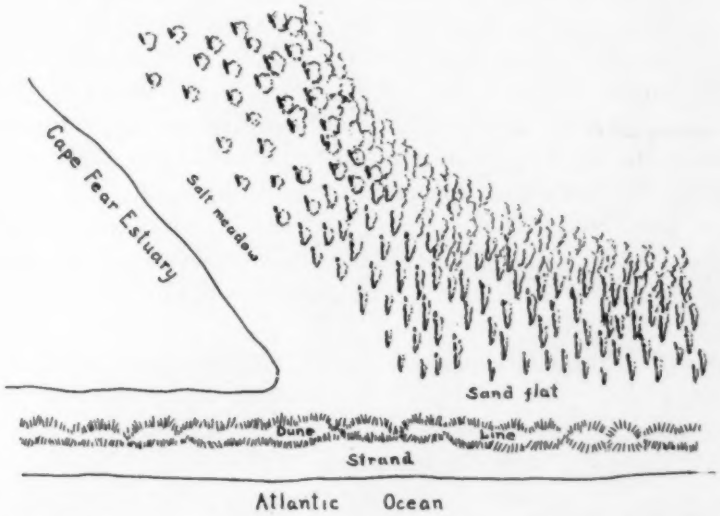

Fig. 3. Section of coast south of Fort Fisher, N. C. Slope form shrubs only in spray zone. Those exposed to wind across estuary but beyond spray zone are of normal form.

Since killing of very young tissues ot the new shoots could readily be induced by one or two applications of sea water in the day period it is clear that the longer spray exposure would result in severe injury to the immature tissues. Only the adult stems and leaves escape in the case of the plants found in the stronger spray zones.

The injury may thus be interpreted as necrosis due to excessive water loss from the young tissues resulting from the osmotic action of high salt concentrations on the unprotected surfaces.

DIFFERENTIAL RESISTANCE OF COASTAL PLANTS

The most resistant woody plant is the water bush (*Baccharis halimifolia*). This fact, however, does not necessarily mean that this shrub will

be found nearest to the sea, because its distribution is also partly controlled by the depth of the water table. It is never seen growing on the dry sides of dunes or even slightly elevated areas. Next in order of resistance are the yaupon (*Ilex vomitoria*) and the wax myrtle (*Myrica cerifera*) which are equally tolerant of salt spray; they are frequently seen merged in common shrub masses.

The only tree on the sea front associated with the shrubs mentioned is the live oak (*Quercus virginiana*) which, assuming a compact shrub-form, is sparingly scattered in the fully exposed zone, but occurs for the most part protected by one or more of the preceding shrubs. On the coast facing northeast, in the vicinity of Kitty Hawk, a shift in the dunes occasionally leaves a live oak exposed to the full force of the ocean wind with its high content of salt spray. This results in a completely one-sided development (fig. 2); new growth being impossible on the spray exposed side, the tender shoots survive only on the protected side of the tree. Such trees show the maximum attainment of the spray form.

Most sensitive of all the arborescent species surviving in the spray zone is the loblolly pine (*Pinus Taeda*). An occasional low specimen was noted in the front zone, but it was always behind a protecting shrub mass.

Through field observations and many tests we found that the young growth of loblolly pine was readily killed under weak spray intensity, but the mature leaves either of the current season or a year old were somewhat resistant. There is a lag in the appearance of the characteristic light sienna color of the necrotic leaves following the application of the salt water. Their tips first show the injury, the necrosis rapidly progressing stemward until the leaves are completely killed. This is then followed by dehiscence of the branch. The observed behavior of the leaves artificially sprayed and dipped in sea water checked with conditions found in the field. In the Fort Fisher area, *Pinus Taeda*, characterized by a slight resistance to the salt, dominated the inner and weaker spray zone.

The only five woody plants occurring and persisting in the spray zone listed in the order of their resistance are water bush, yaupon and myrtle, live oak, and loblolly pine.

Observations on a few representatives of more inland woody plants (persimmon, turkey oak, grape) which by chance were close enough to the sea to be injured showed such a severity of injury to the practically mature leaves that the explanation of their almost complete absence from the spray zones was apparent.

Extensive areas of the turkey oak (*Quercus Catesbaei*) occur along the coast near the sea. Why these trees, so perfectly adapted to the sand soil

habitat, never were found competing with the woody plants of the seaside, had been puzzling to ecologists. Our observations solve this problem. The leaves of this tree cannot even tolerate the weak spray of the inner zone, which is withstood by the pine.

In all of the woody plants except the pines, branch regeneration from lateral buds occurred throughout the growing season. The new growth was not confined to the spring period. Thus the degree of fastigiation in any particular zone is related to the frequency of high winds with their high spray content.

SPRAY ZONE WIDTH

Having learned that the loblolly pine along the coast was the most sensitive of the woody plants able to survive in the weak or landward side of the spray zone, we were able to use this tree as an index in measuring the width of the spray zone at various points along the coast. Myrtle Beach, South Carolina, showed the narrowest width (lowest winds) with a measurement of .1 mile. The Orrell line road transect near Fort Fisher gave .3 mile. The widest spray zone perhaps on the entire coast was that noted at Kitty Hawk on the northeast-facing coast below Norfolk where injury was apparent 1.25 miles inland.

SALT SPRAY AND THE DUNE COMMUNITY

From the observations presented on the restricted number of woody plants able to survive in the salt spray zone compared to the number of woody plants which cannot exist in this zone, it would seem to follow that the same contrast must obtain in relation to the dominantly herbaceous dune community. And this would be especially true since this community occupies the heaviest spray zone of all, that next the strand. To test this matter we transplanted a clump of wire grass (*Aristida stricta*) from an inland sandhill community dominated by long leaf pine and turkey oak to a dune top on April 3. On April 9 almost all the leaves had been killed nearly to the base, and on April 30 the plant gave evidence of being completely dead. Another clump placed 30 yeards inland from the strand showed little injury during the month's exposure.

It seems probable that the distinctive composition of the dune community is based primarily upon the species adaptations to the spray factor. However, much more work must be done on this phase of the problem before a completely satisfactory evaluation of the front dune factor complex may be reached.

SUMMARY

Observations made during the spring of 1937 prove that the repressed

sloping forms of the seaside shrubs ("wind forms" of the literature) are not due to wind but to the killing action of salt spray on the young growing shoots. Such form modifications should therefore be called "spray forms."

Based upon the death within a month's period of *Aristida stricta* transplanted from an inland habitat to the front dunes, it is suggested that the dominants of the ocean dune community are dominant because of their resistance to salt spray.

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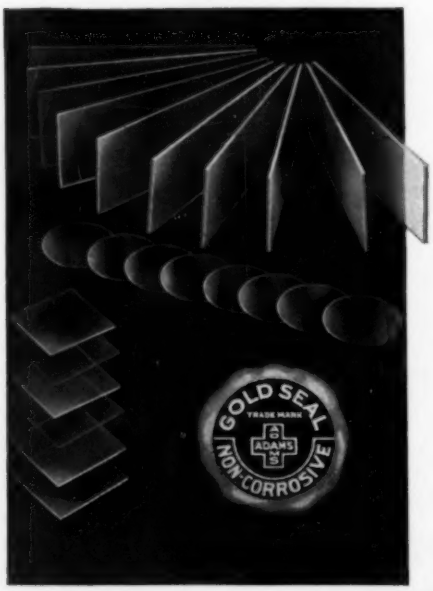

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